VEHICLE ENGINEERING

AGENDA	Presenter:
	Organization/Date: Orbiter/11-15-01

ORBITER	**To Be Presented**
SOFTWARE	**No Constraints**
FCE	**No Constraints**
GFE	**No Constraints**
FLIGHT READINESS STATEMENT	**To Be Presented**

BACKUP INFORMATION

STS-108
FLIGHT READINESS REVIEW

NOVEMBER 15, 2001

Orbiter

AGENDA

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

• Engineering Readiness Assessment	
• Previous Flight Anomalies	To Be Presented
• Critical Process Changes	To Be Presented
• Engineering Requirement Changes	No Constraints
• Configuration Changes and Certification Status	To Be Presented
• Mission Kits	No Constraints
• Safety, Reliability and Quality Assessment	No Constraints
• Special Topics	To Be Presented
• Resolution of AMEC SAIL Anomalies	
• OMS Pod Attach Point 5 Anomaly	
• Lead Level in Water Tank B	
• Vent Door 8 & 9 Actuator Gearbox FOD	
• Rudder Speed Brake PDU Gear Scuffing	
• MLG Wheel Tie-Bolt Hole Corrosion	
• Flight Readiness Statement	To Be Presented
• Backup Information	

	Presenter:
	Organization/Date: Orbiter/11-15-01

PREVIOUS FLIGHT ANOMALIES

	Presenter:
	Organization/Date: Orbiter/11-15-01

STS-105
IN-FLIGHT ANOMALIES

PREVIOUS IN-FLIGHT ANOMALIES

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

STS-105 In-Flight Anomalies, Previous Shuttle Mission (OV-103):

- Two Orbiter in-flight anomaly identified
  - STS-105-V-01: Left OMS Oxidizer Crossfeed Low Point Drain Line B Heater Failure
    - Troubleshooting confirmed the cause to be due to a failed open thermostat
    - Repair and retest is planned
  - STS-105-V-02: Loss of AC2 Phase A During MPM Stow
    - Isolated to circuit breaker - likely a contaminated contact
      - Condition cleared by cycling breaker
    - Plan to R&R circuit breaker and perform failure analysis to compare its condition to other recent failures
  - Details in backup

All Anomalies and Funnies Have Been Reviewed and None Constrain STS-108 Flight

	Presenter:
	Organization/Date: Orbiter/11-15-01

STS-100
IN-FLIGHT ANOMALIES

PREVIOUS IN-FLIGHT ANOMALIES

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

STS-100 In-Flight Anomalies, Previous OV-105 Mission:

- Three Orbiter in-flight anomalies identified
  - STS-100-V-01: FES H_2O Feedline B Zone 3 Heater String 1 Failure
    - Isolated to broken heater ground point wire, which has been repaired and retested
  - STS-100-V-03: WSB 3 Anomalous Temperature Response on Controller B
    - Isolated to failed capacitor in controller - associated capacitor circuit board was R&R'd and retested
  - STS-100-V-04: Vernier Thruster R5D Intermittent Low Chamber Pressure
    - Most likely cause due to this particular thruster's sensitivity to hot propellant with possible contribution of extruded fuel valve seal - thruster has been R&R'd
  - Details in backup

All Anomalies and Funnies Have Been Reviewed and None Constrain STS-108 Flight

	Presenter:
	Organization/Date: Orbiter/11-15-01

CRITICAL PROCESS CHANGES

STS-108 CRITICAL PROCESS CHANGE REVIEW SUMMARY

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Item Reviewed	No. of Items Reviewed	Period or Effectivity Covered	No. Found To Be Critical Process Changes
OMRSD Changes (RCNs)	35	STS-108 Specific & Non-Flight Specific Changes Approved 6/4/01 – 10/5/01	0
OMRSD Waivers & Exceptions	7	STS-108 Specific	0
IDMRD Changes (MCNs)	25	Approved 6/4/01 – 10/5/01	0
IDMRD Waivers & Exceptions	1	Approved 6/4/01 – 10/5/01	0
EDCPs	17	Closed 6/4/01 – 10/5/01	3
Boeing Specifications	83	Released 6/4/01 – 10/5/01	2
Boeing Drawings	935	Released 6/4/01 – 10/5/01	0
Material Review	638	Approved 6/4/01 – 10/5/01	0

- All process changes were reviewed and none constrain STS-108

CRITICAL PROCESS CHANGES

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

EDCP ORB-0156, Fuel Cell Separator Plate Modifications

- This EDCP incorporates modified magnesium separator plates into current fuel cell power section. These plates were developed as a part of Long Life Alkaline Fuel Cell Upgrade project.
- Modification includes changes in sealing material and plate geometry to improve compression set properties and seal retention during production and repairs.

EDCP 1414-507 EDCP0025, MPS 2 Inch Disconnect Bushing Drawing Revision

- This EDCP adds precision cleaning and packaging note to the 2” disconnect 1414-2 and 1414-12 Bushing drawings
- Change will ensure contaminants from the manufacturing process will be properly removed prior to shipping to logistics. Parts stocked for an extended duration will be ready for installation with no additional cleaning required**.**

CRITICAL PROCESS CHANGES

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

EDCP ORB-0156, Addition of New Sealing Epoxy for Fuses

- This EDCP adds Loctite “Durabond” E-30CL epoxy to the current list of epoxies used for the manufacture of fuses.
- E-30CL is currently used in the vendor’s commercial and MIL SPEC fuses and is certified for Orbiter use by test at vendor and WSTF

Boeing Specification MB0150-076, Convolute Tubing

- This specification change clarifies that the presence of Triallyl Isocyanurate (TAIC) on the surface of convolute tubing is normal and not grounds for material rejection

Boeing Specification MA0608-301, Finish Requirements

- This specification change eliminates the use of MB0125-084 (red) adhesive primer for TC code finish applications on the Orbiter. Superior adhesion properties of MB0125-094 (yellow) primer has been demonstrated over several years of Orbiter use.
- The update also clarifies the use of single primer, MB0125-094, for paint repairs in the payload bay.

	Presenter:
	Organization/Date: Orbiter/11-15-01

CONFIGURATION CHANGES AND CERTIFICATION STATUS

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

- **26 Modifications Incorporated During the STS-108 Processing Flow**
  - All certification is processed and approved
  - Total listing of STS-108 modifications and certification details is in backup
- **16 modifications are flying for the first time on STS-108**
  - Summaries to be presented on following pages

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

MCR 19563 SSME Thrust Structure Strain Gauge & Payload Trunnion Latch Accelerometer Instrumentation

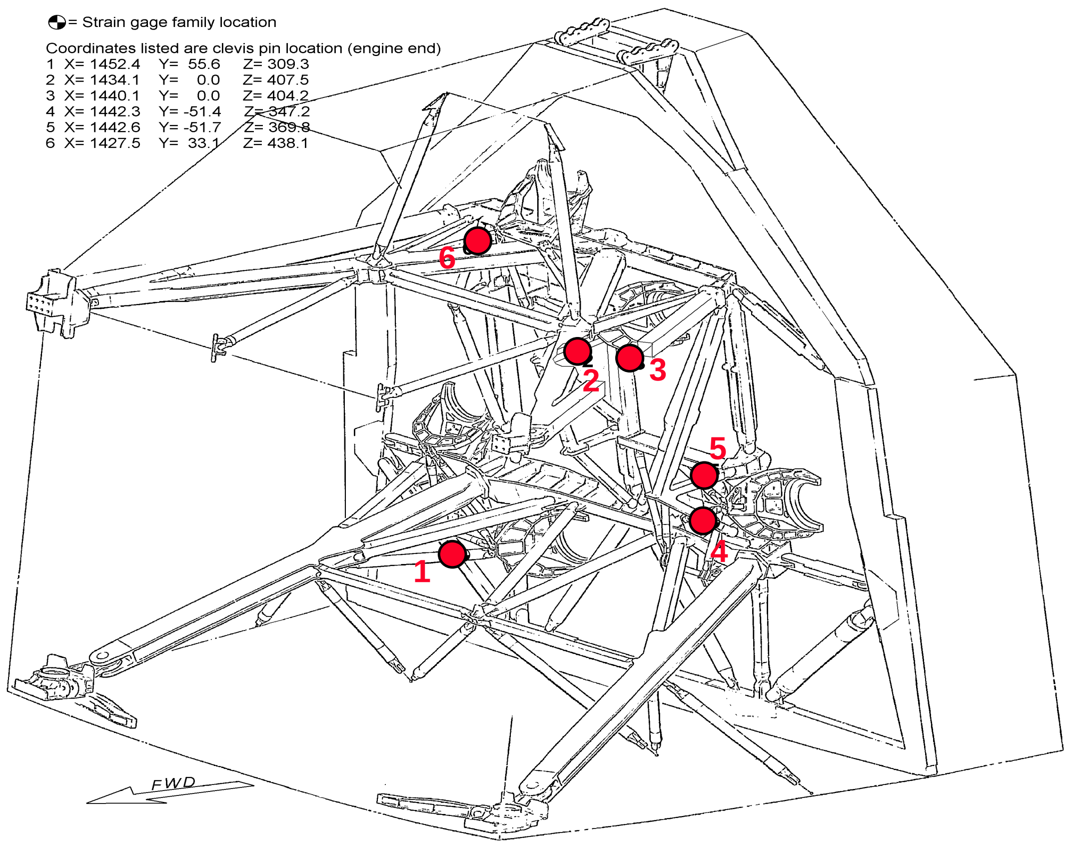
- Thrust Structure Micro-Strain Gauges Units (SGU):
  - Installed Micro-SGU to collect flight strain data on engine 1, 2 & 3 pitch actuator fittings and the "upper beam" which are life limited titanium thrust structure components
  - Conservatism in fracture analysis will be validated to aid in the component life extension
- Payload Trunnion Latch Micro Triaxial Accelerometer Units (TAU):
  - Installed stand-alone Micro-TAU units at four Orbiter latch locations to record actual orbiter to payload interface dynamics, allowing better characterization of MPLM trunnion friction and slip dynamics for loads models
    - Three locations associated with MPLM payload attach points and one reference location at a MACH-1 payload payload attach point
  - Payload community installed Micro-TAU on the payload, as near as possible to the associated payload trunnion locations

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

SSME Thrust Structure Strain Gauge Locations

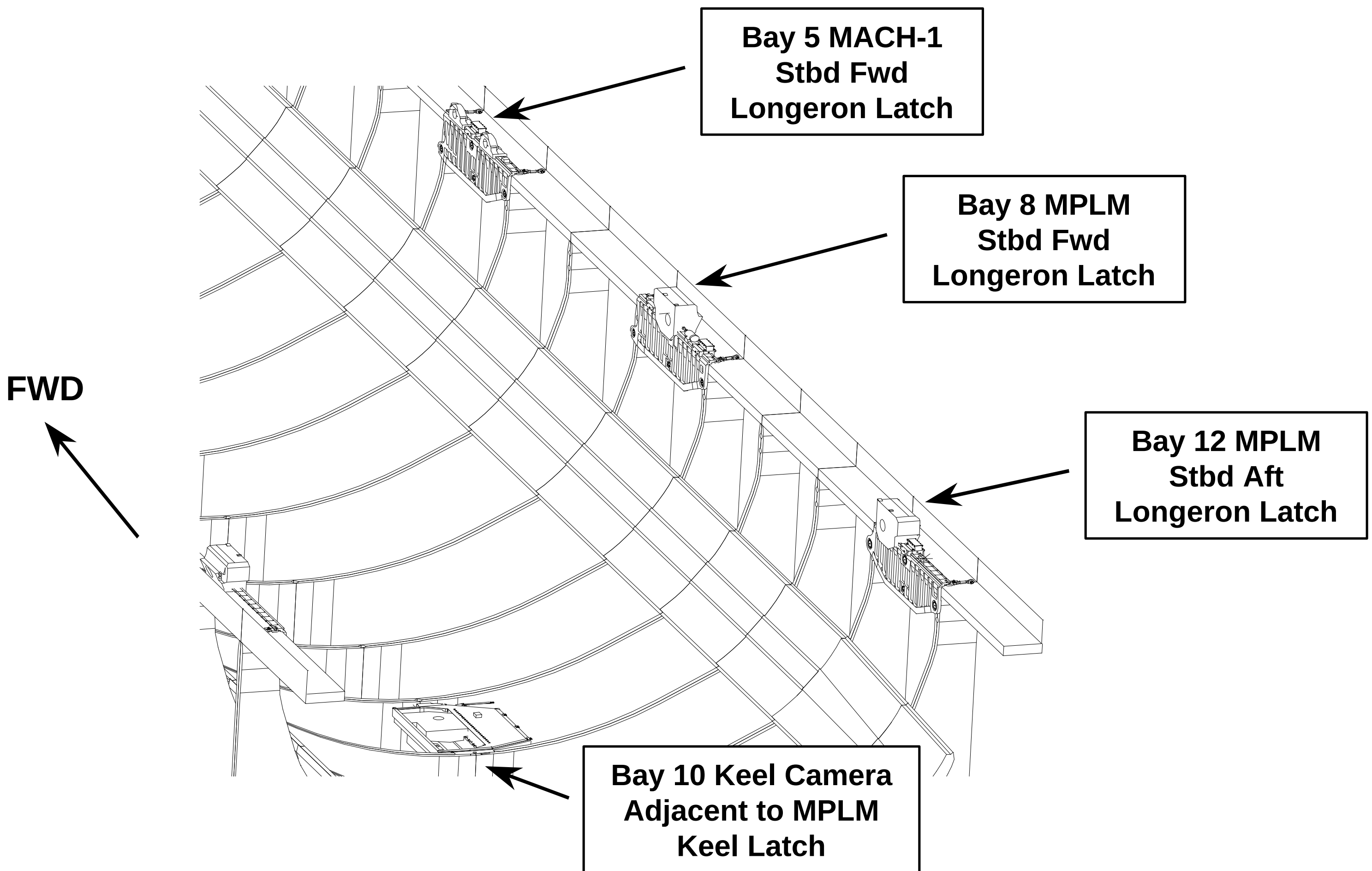


CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Payload Trunnion Latch Micro Triaxial Accelerometer Locations



CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter: Doug White

Organization/Date: Orbiter/11-15-01

MCR 19527 Critical Wire Redundancy Separation

- Separated wiring for 52 of 107 locations where redundant crit 1 functions were routed together in common wire harnesses
  - Reduces risk of loss of a critical system function due to loss of a single wire harness
- The remaining areas will be addressed at OMM due to the intrusive nature of access required

MCR 19596 Separation of Inverter AC Wiring

- Separated redundant AC wire runs in nine of twelve locations where these functions were routed in common harnesses between the inverter distribution and control assemblies in avionics bays 1, 2 & 3 to their respective circuit breaker panels
  - Reduces risk of critical AC bus circuit loss (both primary and secondary AC power) due to a single event
- The remaining 3 locations will be reworked at OMM due to the intrusive nature of access required

- These modifications addressed fleet wiring investigation corrective actions
  - Redundant wires were either separated into existing or new harness runs or separated within a bundle using barrier material (convoluted tubing, teflon or mystic tape)

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

MCR 19533 ET Monoball Production Break

- The harnesses routed to the LH2 and LO2 electrical monoball are in a high traffic area and therefore vulnerable to damage during ground processing operations
  - The harnesses are demated from the monoball for access to the area and temporarily stowed locally, causing repeated harness flexing
- Modification adds a monoball wiring production break and removable monoball harnesses
  - Existing wiring is shortened and terminated at the new production break and new harnesses are routed from the production break to the monoball
    - Design allows these harness to be completely removed from the vehicle and protected during turnaround processing

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

MONOBALL PRODUCTION BREAK HARDWARE

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

MCR 19484   Cargo PC Orbiter Scar Wiring

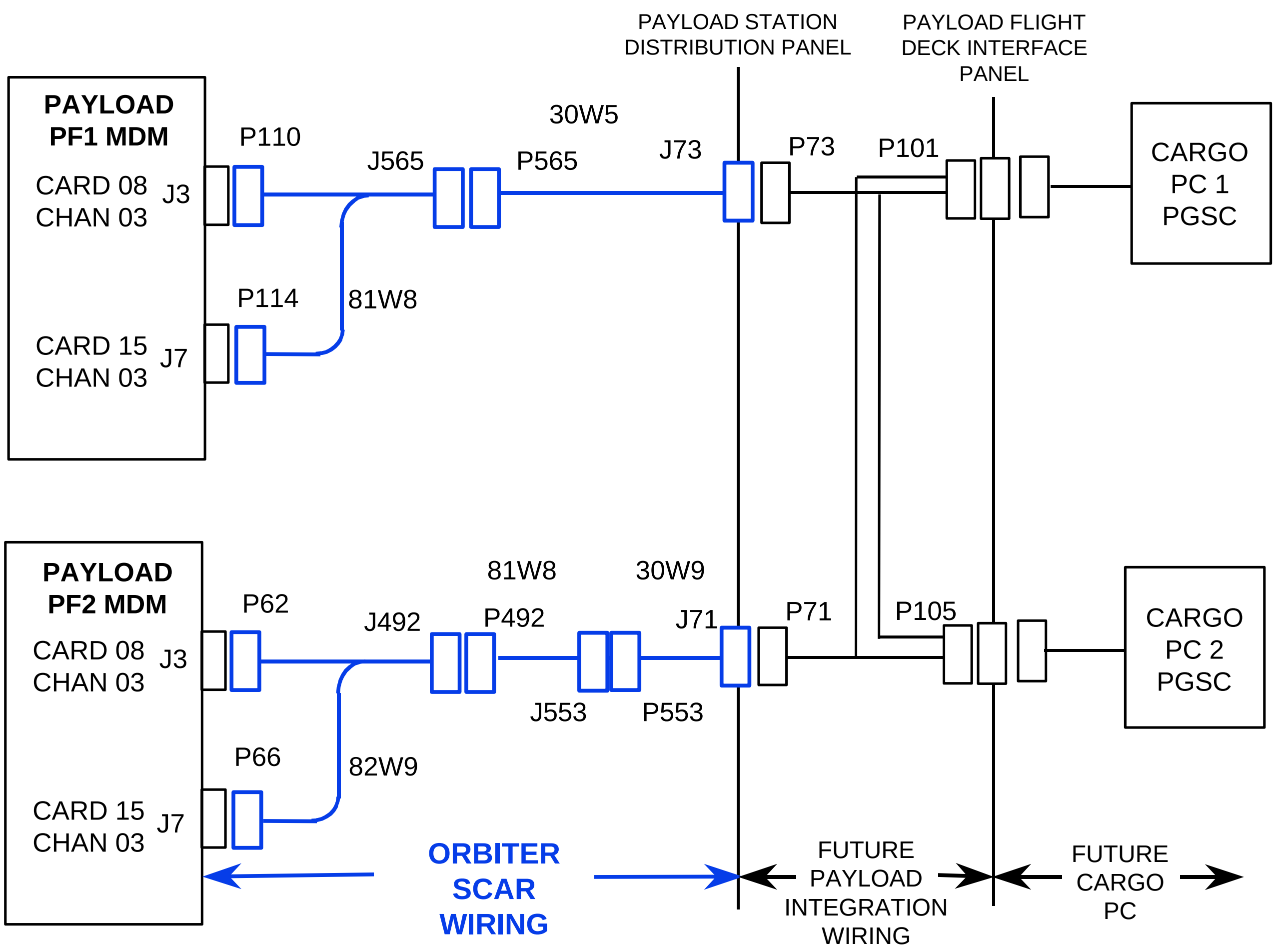
- Cargo PC was developed to decouple vehicle and cargo flight software reconfiguration by utilizing PGSC's to provide software control and monitoring of payloads and payload functions
  - Reduces cargo software mission production template
- The Cargo PC system will interface with payloads and the orbiter GPC via payload MDMs PF1 and PF2 spare channels
- Implementation of Cargo PC involves orbiter scar wiring mods and payload integration wiring mission kits
  - Orbiter crew module scar wiring installed this flow from payload MDMs PF1 and PF2 in avionics bays 1 and 2 to the flight deck payload station distribution panel (PSDP)
  - Payload wiring will be routed from the orbiter interface at the PSDP to a PGSC interface in a flight deck payload interface panel (typical aft flight deck SMCH installation)
    - To be installed at a later flight

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

SIMPLIFIED CARGO PC WIRING DIAGRAM



CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

MCR 18509 Condensate Separation and Collection

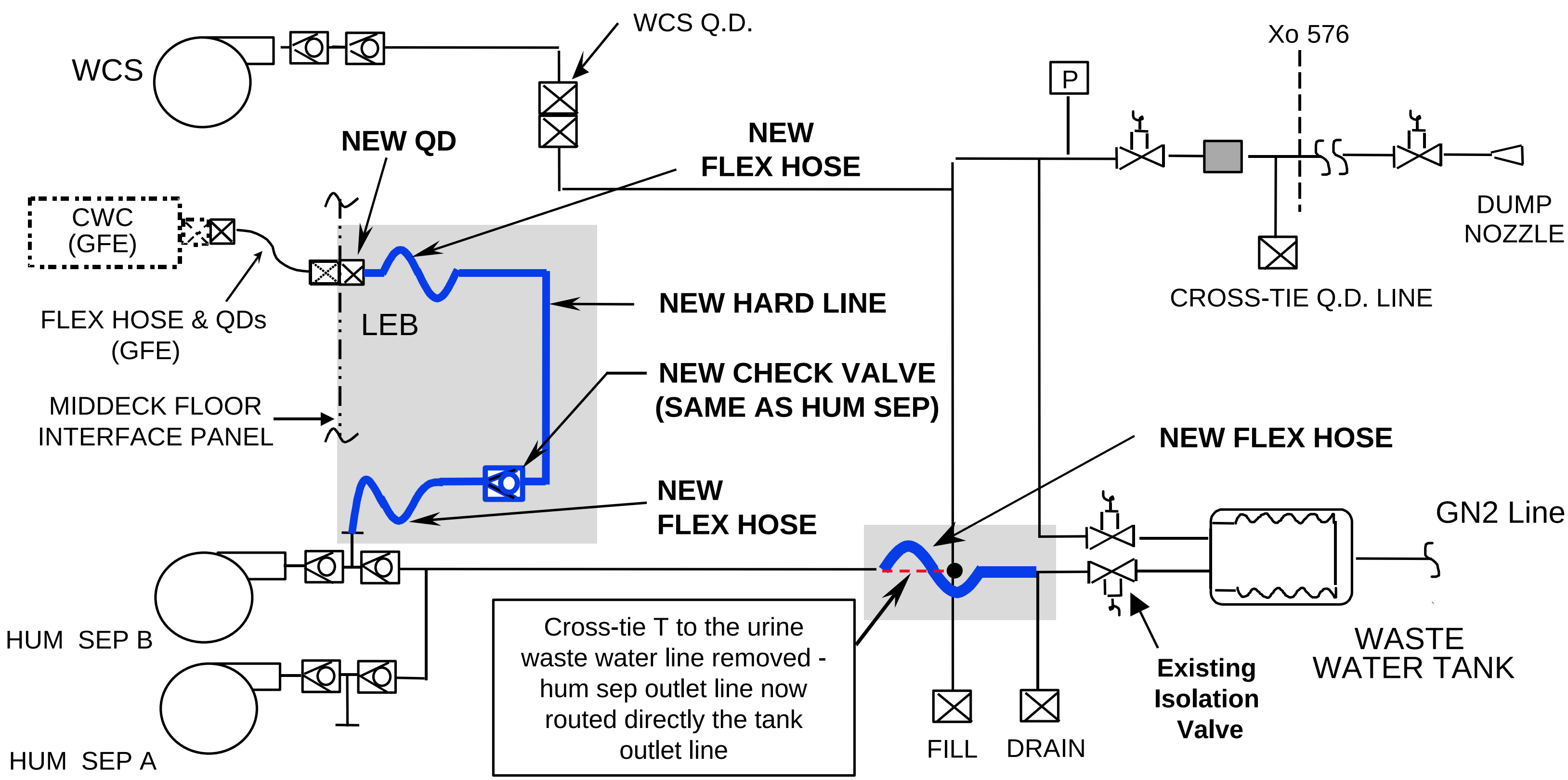
- Modification driven by ISS requirement that Orbiter waste water dumps be inhibited during docked operations to preclude contamination of sensitive station components
  - Mandatory capability prior to installation of the JEM module
  - By collecting condensate in CWC's, waste tank ullage for urine is increased, extending the time between waste water dumps
- The ECLSS waste management system was modified to allow condensate effluent to be separated from urine waste water
  - Provides the capability to collect the separated condensate in CWC's at a permanent middeck crew interface QD, eliminating the need to install and route a temporary DTO hose
- Mod also plumbs the humidity separator outlet line directly to the waste tank, allowing the waste tank to be isolated from the condensate line
  - Prevents urine from being introduced during condensate collection operations

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Condensate Separation Mod Schematic Representation



CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter: Doug White

Organization/Date: Orbiter/11-15-01

MCR 19033 Orbiter Umbilical Plate Gap Delta Pressure Transducers

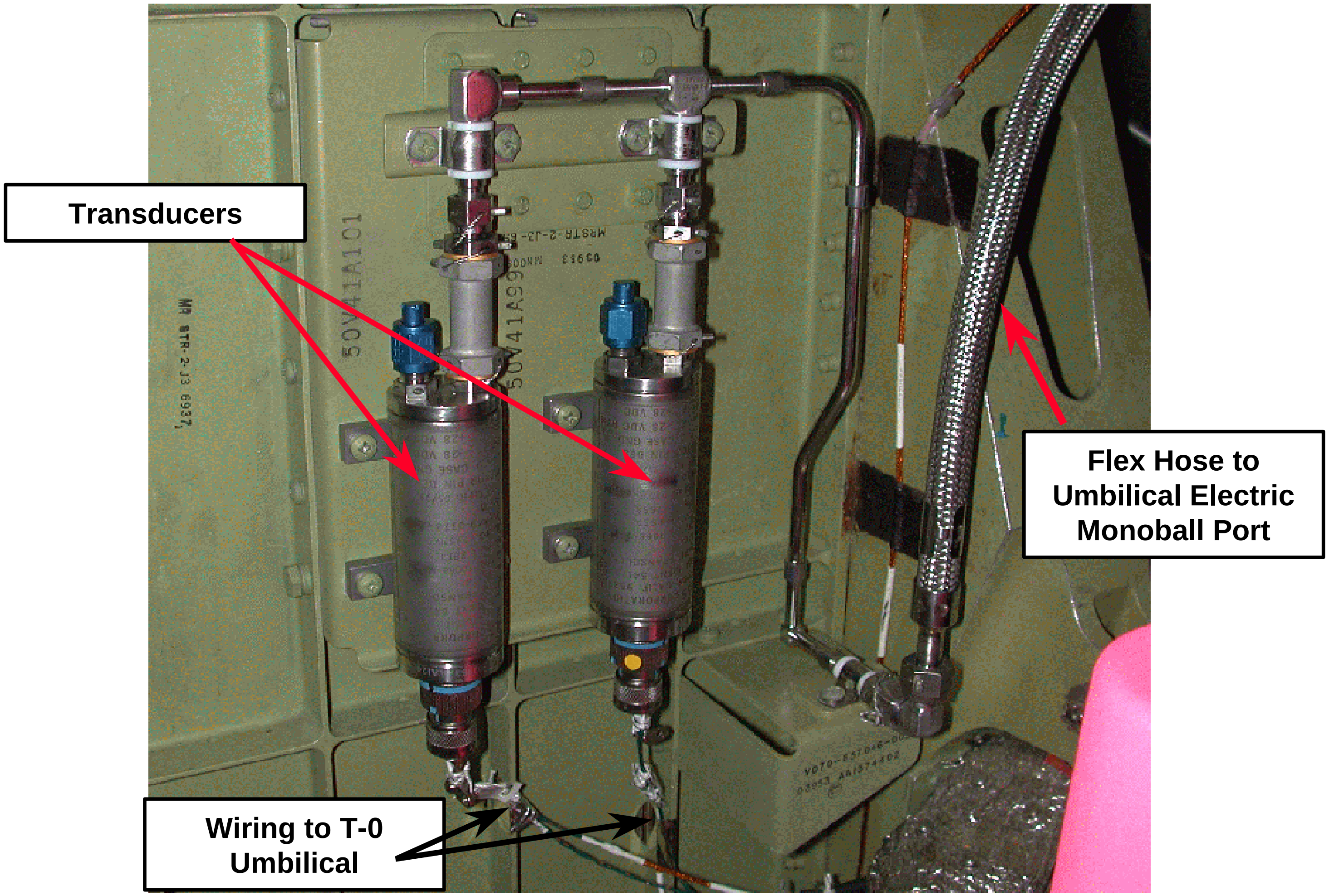
- Installed pressure transducers to measure purge pressure in the LH2 and LO2 ET/Orbiter disconnect plate gap
  - Flexhoses and hardlines port the cavity pressure at the electrical monoball to two redundant pressure transducers
  - Wiring to the T-0 umbilicals routes transducer signals to LPS, serving as a ground measurement only
- Provides direct verification of positive plate gap cavity purge pressure during cryo loading
  - Purge protects against hazardous gas ignition and GN2 or air intrusion which could result in component icing
- Current method only monitors MLP purge supply pressure, indicating flow, but not actual plate gap pressure
  - Requires lengthy operations to setup purge at Orbiter/ET mate
- Not planned for use this flight - associated ground side modifications to be in place next flight
- Future plan is to use the existing purge set up and LCC (25 % drop in supply pressure) with the new instrumentation for 4 flights to collect and evaluate comparative data

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Umbilical Plate Gap Delta Pressure Transducer Installation



CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

MCR 19518 APU Air Half Coupling Upgrade

- Six Orbiter APU Air Half Couplings (AHC's) are used to service APU system hydrazine fuel and GN2 at the aft fuselage sidewall servicing panels
  - Three AHC's for fuel and three for GN2, one each for the three APU systems
- The existing design J.C. Carter AHC's have a history of poppet leakage, resulting in ~ 74 AHC R&R's in program history
  - Replacement requires an extensive amount of SCAPE ops activity in a limited work space area with high potential of collateral damage to adjacent area subsystem hardware
  - The AHC has to be removed and sent to the HMF for poppet seal replacement, involving cutting and re-welding the housing
- Modification replaces the J.C. Carter AHC's with the more reliable Orbital Science AHC's currently used in the OMS/RCS system
  - Only 6 OMS/RCS fuel AHC R&R's since return to flight
  - The AHC poppet seal replacement can be performed from outside the aft fuselage, at the servicing panel, without the need for recycling the AHC to the HMF for repair

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

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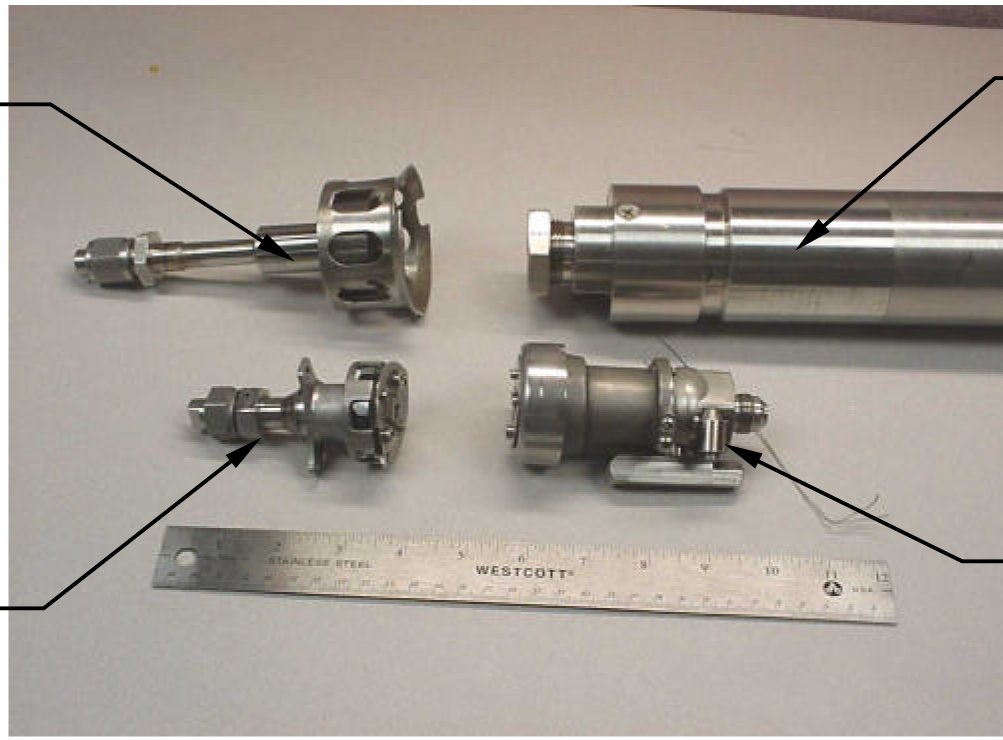
Orbiter/11-15-01

NEW ORBITAL SCIENCE COUPLINGS REPLACE JC CARTER COUPLINGS

Orbital Science AHC



Ground Half Coupling (GHC) also changed to Orbital Science type

JC Carter AHC

JC Carter GHC

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

MCR 19427 MPS/SSME Interface Pre-Cast Foam Closeout

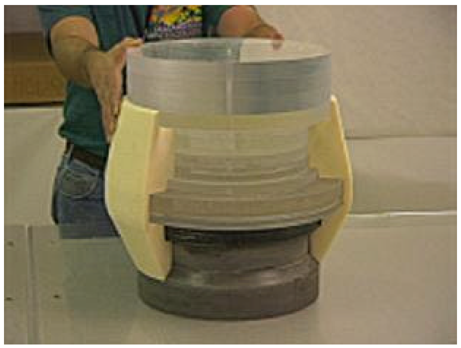
- Foam insulation of the 12” LH2 feedline (F1) joint and the 2” recirculation return line (F4.3) joint at the Orbiter / SSME interface is a time and labor intensive task
  - Hazardous operation requiring local clears during foam pour
  - Removal process generates dust and contaminate in the aft
- New pre-cast foam closeout sections for these joints greatly enhances installation and removal process and reduces process time
  - Sections are taped in place with LT-80 tape
  - Voids between the foam sections and the feedline are filled by injecting RTV through pre-drilled holes in the foam
  - Utilizes same certified materials as current joint insulation
- Thermal characteristics verified by extensive testing on Stennis SSME Test stand and analysis
  - Thermal analysis & test data show comparable heat flux between the original and new foam installation designs
- Design concept fit-checked at each engine joint location
- The new design is being flown on the engine 1 12” LH2 feedline (F1) joint for STS-108

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

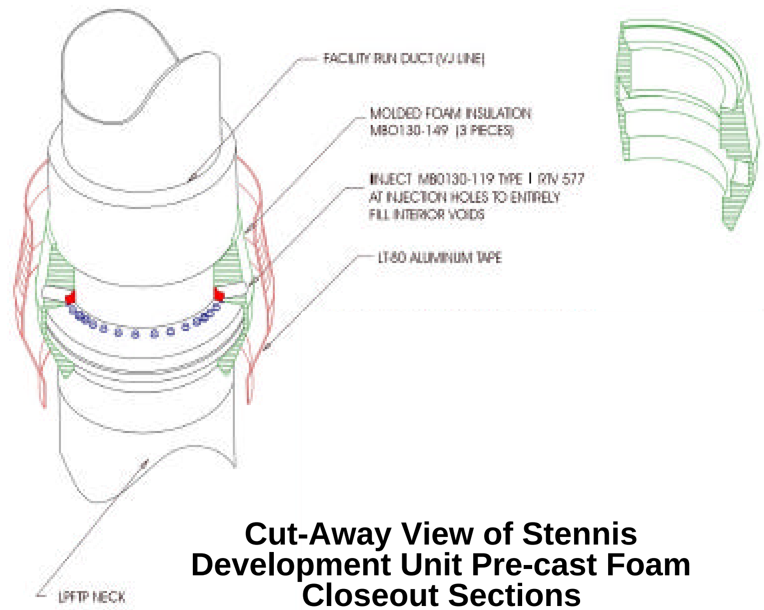
Organization/Date:
Orbiter/11-15-01

MPS/SSME INTERFACE PRE-CAST FOAM CLOSEOUT



Fit Check of Stennis Development Unit Pre-cast Foam Closeout Sections

Orbiter Pre-cast Foam Closeout Sections Taped in Place



Cut-Away View of Stennis Development Unit Pre-cast Foam Closeout Sections

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

MCR 19483 Body Flap Fitting Bolt Anti-Spin Retainer

- The body flap actuator attach fitting bolts are checked for torque loss and re-torqued if required after each flight
  - Eight bolts for each of four fittings are preloaded to maintain joint stiffness and prevent joint separation
  - To perform the torque checks, the body flap stub carrier and access panels require removal and the body flap positioned to allow access for personnel and tools to hold the bolt heads
    - Torque checks are then performed on the fastener nuts in the aft fuselage
- The modification adds permanent bolt head retainers to the fittings, which restrain the bolts from turning
  - 17 of 32 bolt locations were modified this flow - the remainder will be worked at OMM
  - When completed, will significantly reduce the effort required to perform the torque check task and reduce the risk of access area collateral damage
    - Aft fuselage access only will be required to perform the torque checks

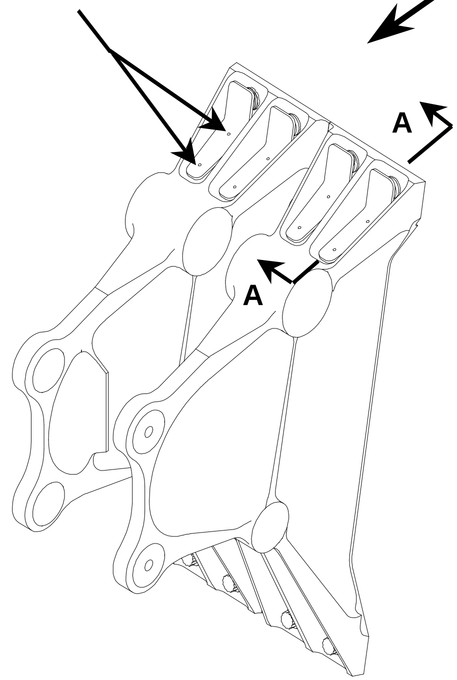
CONFIGURATION CHANGES AND CERTIFICATION STATUS

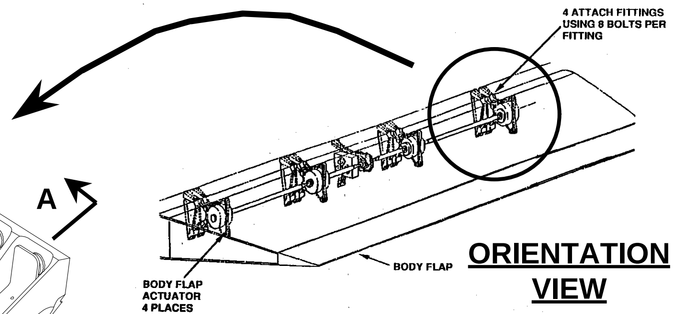
Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

BODY FLAP ACTUATOR FITTING ANTI-SPIN RETAINER

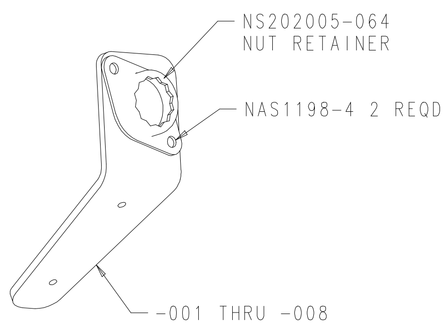
3/16 TI HI-LOK
2 REQ'D FOR EACH
RETAINER

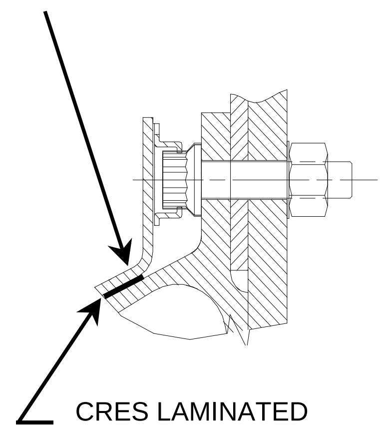




ORIENTATION VIEW

CRES RETAINER FITTING
8 LOCATIONS PER FITTING
AT EXISTING 3/8 DIA BOLT HEAD





CRES LAMINATED
SHIM

SECTION A-A

TYPICAL CRES FTG WITH CRES NUT RETAINER

VIEW LOOKING FORWARD AT BODY FLAP FITTING

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

MCR 18872 Panel L4 Circuit Breaker Replacement

- The 5 amp circuit breakers in positions 137 and 138 on panel L4 were changed out with the correct size 3 amp circuit breakers
  - Documentation and closeout photo review during the OV-104 STS-104 flow revealed that these circuit breakers, which provide power to the two radiator panel isolation valves, were oversize
- Mod eliminates the potential of a short downstream of the circuit breaker causing an over-current shut-down of the associated inverter (1R3 condition)

MCR 19309 Vertical Tail TPS Inspection Port Mod

- Removal of two TPS tiles has been required for fastener removal access to perform borescope structural inspection of the vertical tail tip forward spar shear pin
- Modification changes the local TPS tile configuration (4 tiles), making the footprint of one of these tiles large enough to incorporate a removable ceramic plug, integral to the tile
  - Allows the fastener to be removed to perform the structural inspection without tile removal

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

MCR 19652 TEPC Mounting Adapter Plate Mod

- Eliminated minor interference between the Tissue Equivalent Proportional Counter (TEPC) and adjacent window shade assembly located in the crew module interdeck access area
  - Shifts attach hole pattern on the TEPC mounting adapter panel away from the window shade container

MCR 19554 Elevon Flipper Door Trailing Edge Bulb Seal Mod

- The flipper door trailing edge bulb seals aid in maintaining the shape and positive contact of the flipper door trailing edge seal assembly to the elevon rub panel
- These seals occasionally become dislodged from their retainers and displaced in flight
  - Repair or replacement of loose or lost seals a time consuming processing task
- Modification corrects the condition by adding fasteners to positively hold the bulb seal in position

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

MCR 19531 ET Separation Camera Mod

- STS-108 will be the first flight of the redesigned GFE ET umbilical 35 mm separation camera
- Orbiter structural interface analysis was performed and associated certification and ICD updated for the heavier camera design
- Installation engineering enhanced by utilizing tech orders to install cameras, providing better documentation flexibility in camera manifesting

MCR 12999 Wing to Fuselage Bolt Torque Change

- Increased the lower torque limit on the Xo 1191 wing-to-fuselage attach bolts (1 LH side / 1 RH side)
  - Ensures adequate preload over the entire torque range allowable to prevent the potential of local joint gapping

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

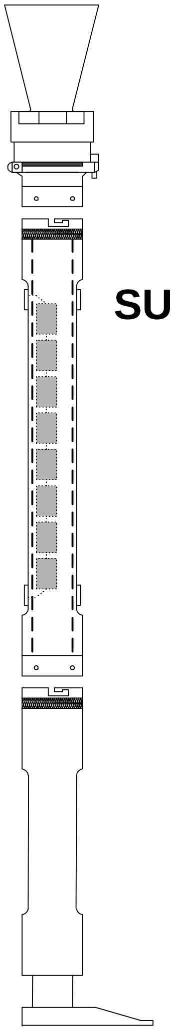
Shuttle Urine Pre-treat Assembly (SUPA)

- Modification also driven by ISS requirement that Orbiter waste water dumps be inhibited during docked operations to preclude contamination of sensitive station components
  - Mandatory capability prior to installation of the JEM module
- Storing pure urine in Orbiter waste tank promotes higher probability of alkaline solids formation
  - Solids could contaminate/occlude WCS components resulting in loss of WCS/Orbiter waste water system function and/or ability to dump
  - Solids formation is prevented by “pre-treating” urine
  - Solid Oxone (potassium monopersulfate) was selected as an anti-precipitation agent
- STS-97/4A was first flight of SUPA
  - Consisted of an eight-tablet configuration

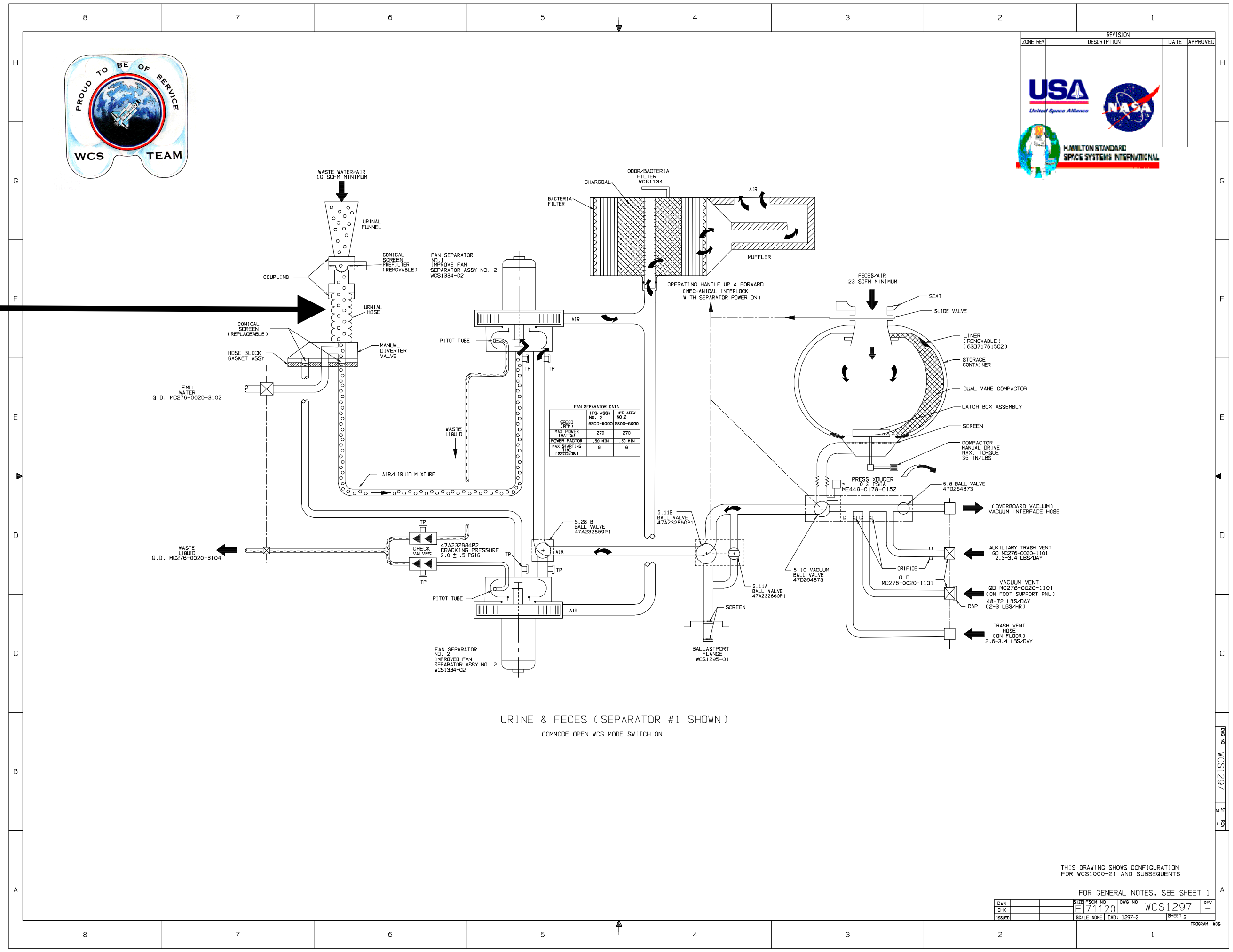
CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01



SUPA



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CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

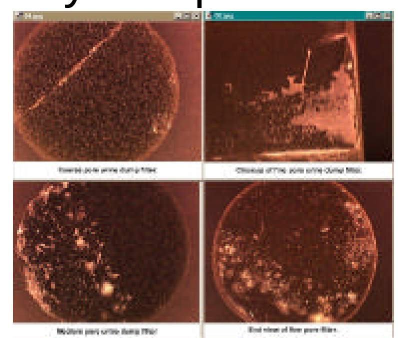
Organization/Date:
Orbiter/11-15-01

Shuttle Urine Pre-treat Assembly (SUPA)

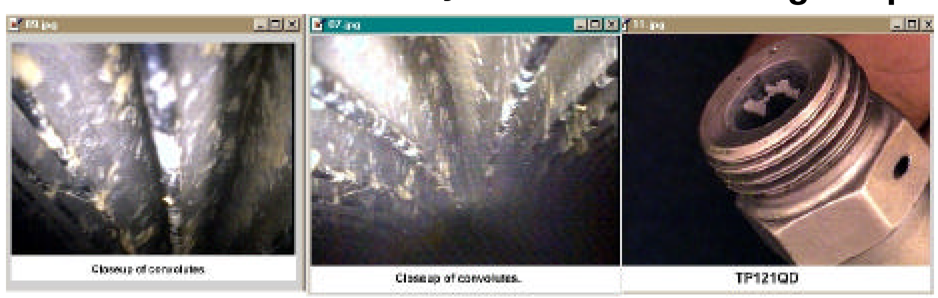
- After STS-97/4A, “Uric acid” deposits found in WCS and Waste Water Management System (WWMS)
  - Significant blockage found in WCS fan separator pitot tube
  - Deposits found in waste tank and high-capacity dump filter

Rotating Separator Bowl

Stationary Pitot Tube



High-capacity Dump Filter



Orbiter Waste Tank and Plumbing

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter: Doug White

Organization/Date: Orbiter/11-15-01

Shuttle Urine Pre-treat Assembly (SUPA)

- Unable to re-create STS-97 deposits through either static or dynamic tests
  - Deposits most likely 0-g phenomena
- Science community derived new SUPA requirement
  - Shuttle WCS: individual void-by-void pH must be in-between 5.0-7.5
  - Shuttle waste tank: aggregate urine pH must remain in-between 5.0-7.5
  - pH lower than 5.0 promotes “uric acid” deposits, while pH greater than 7.5 promotes “alkaline” deposits

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Shuttle Urine Pre-treat Assembly (SUPA)

- STS-108/UF1 Configuration
  - 2-tablet SUPA
  - Daily hose change-out after crew wake
  - 19-day qualification test successfully executed, all pH values meet requirement
- Flight Readiness
  - SUPA hardware is planned for delivery to KSC by L-10
    - CB, USA Ground Ops, and MOD have been notified, no issues noted
  - Final certification is planned for completion by 19 NOV 01

	Presenter:
	Organization/Date: Orbiter/11-15-01

SPECIAL TOPICS

SPECIAL TOPICS FOR THE STS-108 FLIGHT READINESS REVIEW	Presenter: Doug White Organization/Date: Orbiter/11-15-01

Topic	Presenter
• Resolution of AMEC SAIL Anomalies	Doug White
• OMS Pod Attach Point 5 Anomaly	Doug White
• Lead Level in Water Tank B	Doug White
• Vent Door 8 & 9 Actuator Gearbox FOD	Doug White
• Rudder Speed Brake PDU Gear Scuffing	Doug White
• MLG Wheel Tie-Bolt Hole Corrosion	Doug White

RESOLUTION OF AMEC SAIL ANOMALIES

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

Observation:

- AMEC S/N 10 experienced multiple failures during SAIL burn-in testing in July 2001
- Review of AMEC/EMEC burn-in test data found additional potential failure indications which had occurred on various AMEC units

Concern:

- Anomalies could occur on fleet AMEC/EMEC units during flight
  - Seven anomalies identified involved SRB ignition and separation PIC arm and fire functions and ET/Orbiter forward fire function
  - Required determination of root cause of failures to ensure that there are no inherent technical issues with AMEC/EMEC hardware

RESOLUTION OF AMEC SAIL ANOMALIES	Presenter: Doug White Organization/Date: Orbiter/11-15-01

Actions Taken:

- AMEC Tiger team was formed to address and resolve these AMEC SAIL anomalies
  - Completed data reviews to identify all SAIL AMEC burn-in test anomalies
  - Established fault trees for all identified anomalies
  - Performed analysis, simulation, and testing to isolate, understand, and determine root causes and corrective actions for all anomalies
- Four anomalies were related to SAIL instrumentation and incorrect measurement problems
  - Corrective actions are being put in place at SAIL
    - Instrumentation hardware (pin) discrepancies repaired
    - Minor wiring changes implemented to eliminate a sneak signal ground path within SAIL instrumentation
    - The SAIL ICD and test procedures will be revised to use the same signal ground interfaces as the Orbiter for SRB Ignition function

RESOLUTION OF AMEC SAIL ANOMALIES

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

Actions Taken (Cont):

- Three anomalies were determined to be the result of missing ground path inductors internal to AMEC S/N 10
  - Attributed to a one-time isolated event and inspection escape occurring during initial hardware build
    - Analysis, testing, data and build paper review confirmed there are no other missing components on all AMEC flight hardware
  - Corrective action in place to prevent any potential future occurrence
    - Procedural and LRU ATP changes
  - Testing and analysis confirmed that OMRS testing would screen for the failure mode / missing inductors

Acceptable for STS-108 Flight:

- Root cause of all anomalies were isolated, are understood, and corrective actions are identified
- No inherent technical or safety issues with any AMEC hardware

OMS POD ATTACH POINT #5 ANOMALY

Presenter: Doug White	**Organization/Date:** Orbiter/11-15-01

Observation:

- Holes in the attach point 5 “puck” assembly on OMS pods LP05 and RP05 were found discrepant and elongated
  - Worst case hole elongation found on LP05 or RP05 was 0.030

Concern:

- Condition of the LP04 and RP01(OV-105 OMS pods) attach point 5 puck attach holes is unknown

Discussion:

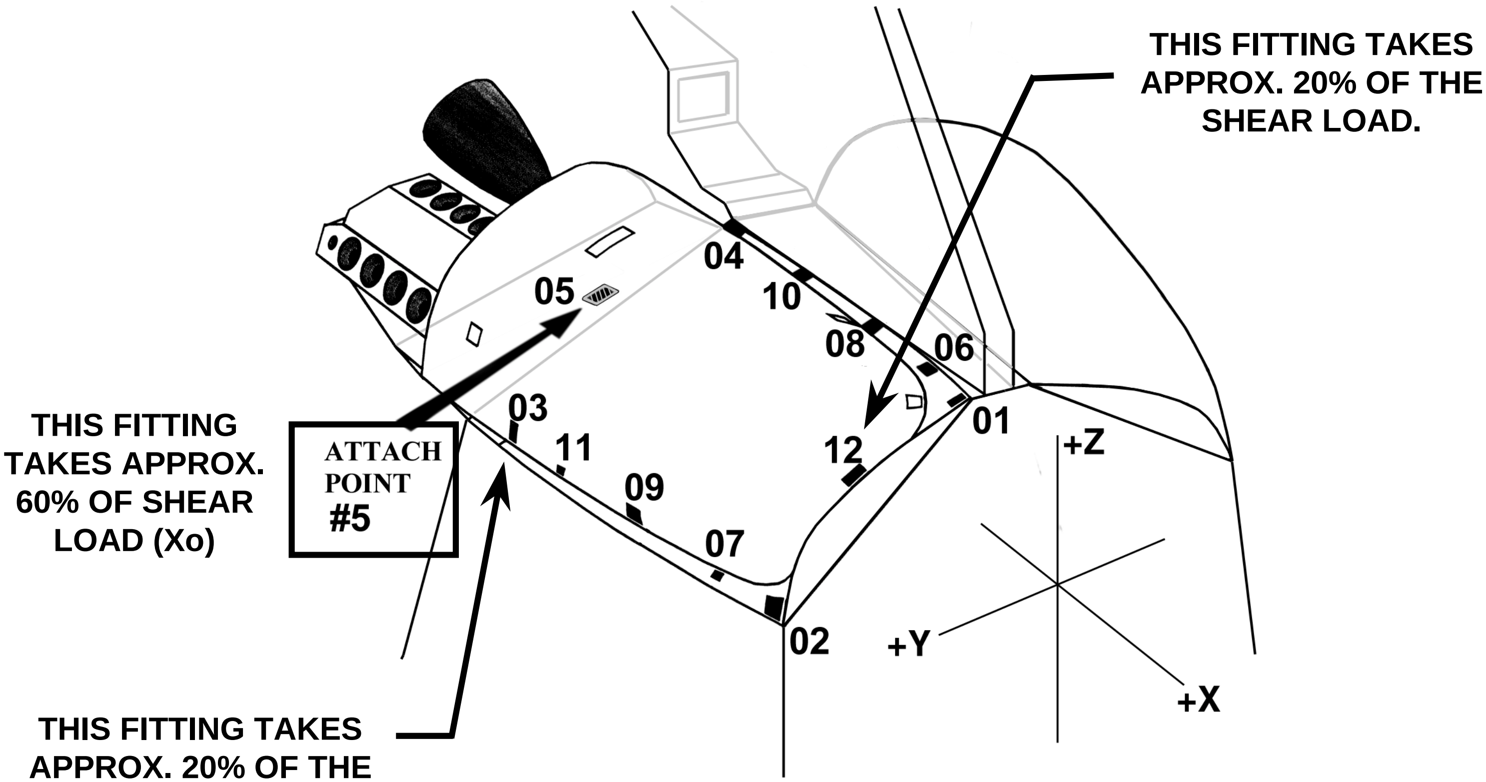
- The OMS pods are bolted to the Orbiter at 12 attach points
- Attach point 5, located at the aft centerline of the pod, carries 60% of the Xo load by design
- The attach point 5 nut element is secured to the pod by means of a puck assembly
  - The puck assembly is installed with fourteen 5/16” bolts
    - Eleven of the 14 bolts are required to meet the design-load 1.4 factor of safety
  - The puck nests in a boss in the OMS deck with a nominal 0.030 gap between the puck and boss

OMS POD ATTACH POINT #5 ANOMALY

Presenter: Doug White

Organization/Date: Orbiter/11-15-01

OMS Pod Shared Shear Load Locations



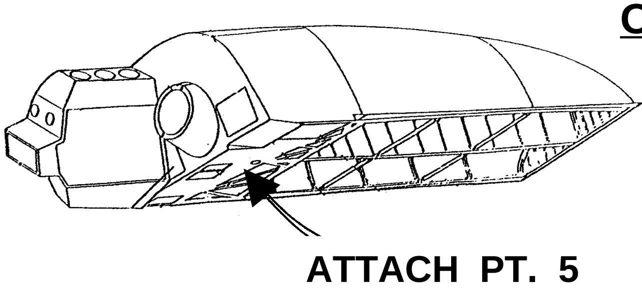
(RH SHOWN, LH OPPOSITE)

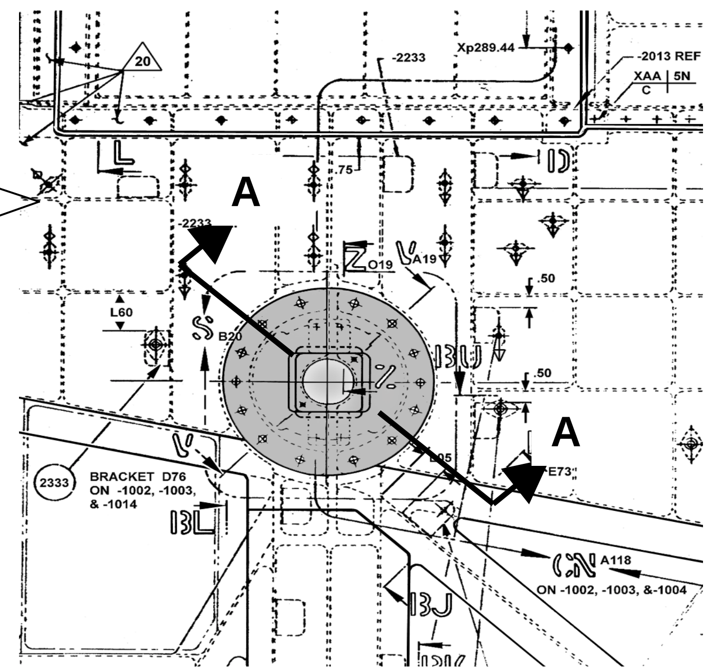
OMS POD ATTACH POINT #5 ANOMALY

Presenter: Doug White

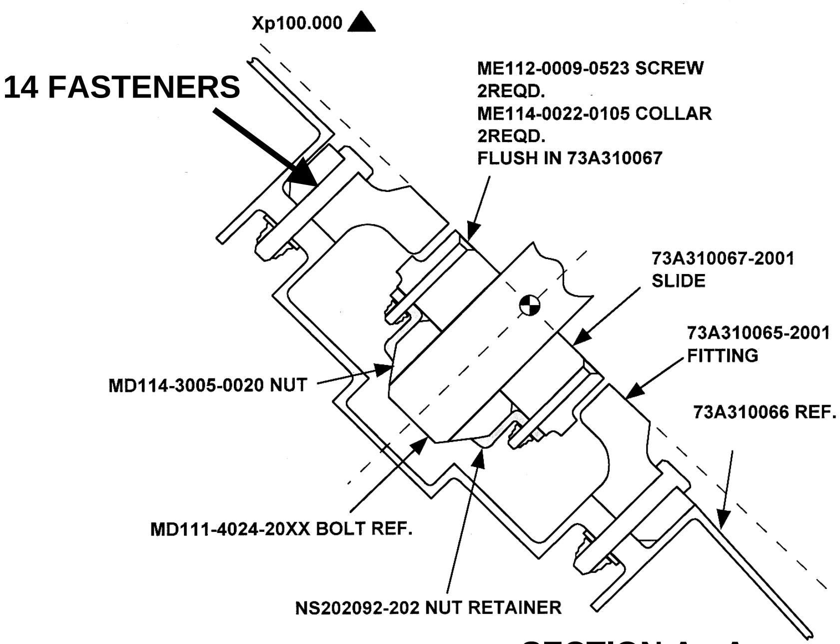
Organization/Date: Orbiter/11-15-01

OMS Pod Attach Point #5 Orientation





VIEW LOOKING OUTBD AT ATTACH POINT # 5



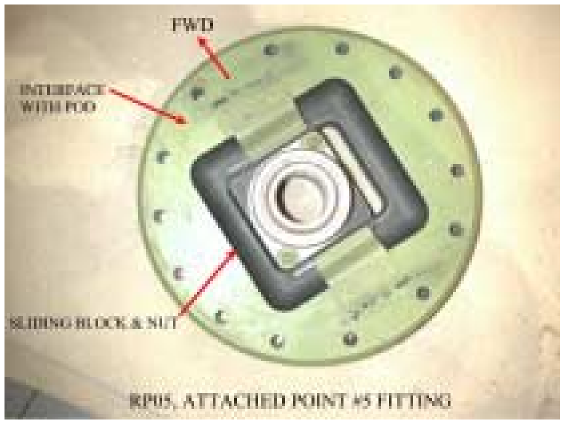
SECTION A - A

OMS POD ATTACH POINT #5 ANOMALY

Presenter:
Doug White

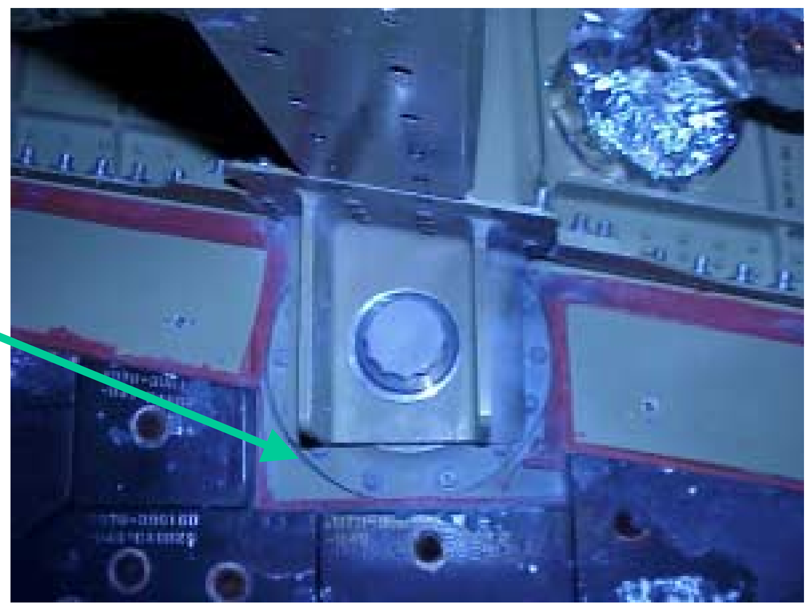
Organization/Date:
Orbiter/11-15-01

PUCK



BOSS

Gap area between puck & boss



OMS POD ATTACH POINT #5 ANOMALY	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Actions Taken:

- Since the condition of the RP01 and LP04 attach point 5 puck holes is unknown, worst-case condition tests were conducted to demonstrate puck attach bolt capability
- Tests designed to show the capability of one bolt in a “tight” hole to deform until other bolts or the boss around the puck could pick up a share of the load
  - Tests reflected a 0.045 elastic capability of a single bolt/joint
  - Bolt/joint has approximately 0.180 plastic capability prior to failure

Tests indicate all bolts and the OMS floor (through contact between puck and boss) would share the load prior to permanent deformation or failure of any bolt

OMS POD ATTACH POINT #5 ANOMALY	Presenter: Doug White Organization/Date: Orbiter/11-15-01

Actions Taken: (Cont)

- Measurement of OV-105 pods confirmed that gaps around the pucks are within the elastic capability of the bolt in the +X direction
  - Worst case +X gap was .030 on RP01

Risk Assessment / Acceptability for STS-108 Flight:

- Tests show that reasonable assumption of 0.030 hole elongation (LP05 and RP05 three-sigma condition) on LP04 and RP01 (OV-105) can be tolerated with significant conservatism
- Tests show that largest measured gap between puck and boss can be tolerated without failure

LEAD LEVEL IN WATER TANK B

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

Observation:

- Post-servicing water samples (.09 and .07 mg of lead/liter) from tank B exceeded the NASA SE-S-0073 Fluid Spec lead requirement of .05 mg/liter

Concern:

- No prior history of exceeding the lead level

Discussion:

- OMRSD requires a tank B water purity check post-servicing
  - Primary purpose is to verify bacteria level—the lead content sample is for info only
  - Tank B water samples met the bacteria levels requirements
- Lead level in water tanks C and D may also be high
  - Tanks B, C and D were all serviced with the same GSE water
- Troubleshooting and sampling determined lead came from the GSE water servicing unit
- Water Management System hardware contains no lead

LEAD LEVEL IN WATER TANK B

Presenter: Doug White

Organization/Date: Orbiter/11-15-01

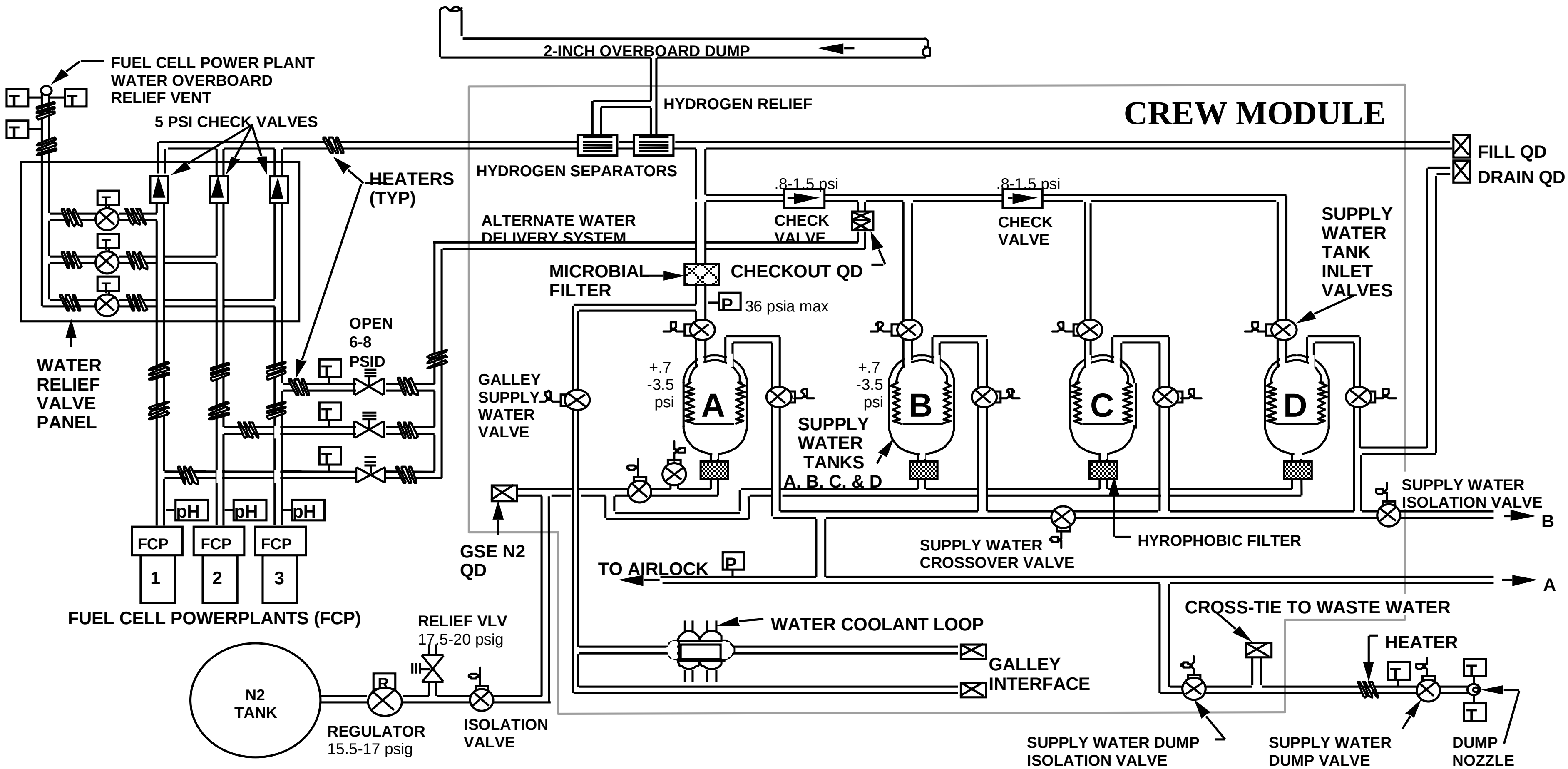
Discussion (Cont):

- Tank A water is used for crew consumption
  - Tank A water met the SE-S-0073 spec requirements
  - Tanks A and B are not planned to be ganged together for this flight, therefore, the risk of cross-contaminating water in tank A with tank B water is remote
- Water from tanks B, C, and D will be used by the Flash Evaporator Subsystem (FES) during flight
  - These tanks are ganged together and will be refilled or topped off with fuel cell water, which will eventually dilute lead to below specification levels
- Tank C water may be used to refill water tanks in the EMUs after an EVA
  - One EVA planned for day 6, by which time, the lead level in tank C would be diluted to below specification requirements
- Dissolved lead, at these levels, is not a concern for either the FES or the EMU sublimator

LEAD LEVEL IN WATER TANK B

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

Supply Water Management System



LEAD LEVEL IN WATER TANK B

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

Actions In Work:

- Troubleshooting plan in work to isolate and correct lead source on the GSE servicing side

Acceptable for STS-108 Flight:

- Source of lead determined to be from the GSE water servicing unit - no Orbiter source for lead
- Tank A water, which is used for crew consumption, met specification requirements
- Tank B water will not be used for crew consumption or for ISS transfer water
- Dissolved lead is not a concern for the FES or the EMU
  - Water levels for tanks B,C and D will be refilled or topped off with fuel cell water, which will dilute lead to below specification level early in the mission

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Observation:

- During disassembly / inspection of a LH Vent Door 8 & 9 actuator (S/N 16) at NSLD, two loose metal bearing shields were found stuck to the gearbox wall

Concern:

- FOD in gearbox creates the potential for a jam (crit 1R/2)

Background:

- Actuator was originally removed from OV-104 and sent to NSLD for intermittent limit switch failures on STS-106
  - First repair in the history of this actuator
- One switch replaced, switch mechanism adjusted, motors replaced
  - When switch mechanism cover was removed, two loose washers were found, which did not originate from the switch mechanism
    - One stuck to cover with grease, one at base of switch/cam stack
    - PRT concluded that these washers were inadvertently left in the switch assembly housing area during initial assembly

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Background (Cont):

- Actuator subjected to and passed ATP
- During dielectric strength test, voltage inadvertently set to over double required level
  - Required replacement of both motors again and three switches
- During second motor replacement, technician noticed one of two gearbox input pinion gears was difficult to rotate by hand
- Gearbox was disassembled to determine cause of binding
- Several observations made upon disassembly:
  - Additional binding found in output shaft planetary gearset (Fig 2)
  - Bearing holes in input pinion gear housing measured and found to be slightly undersized (Fig 2)
    - Possible cause of binding since bearing could not be completely seated
  - One output shaft planet gear had damage on bearing shield (Fig 3)
  - Two loose bearing shields found stuck to the gearbox wall
    - One differential bearing missing shield (Figs 4)

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

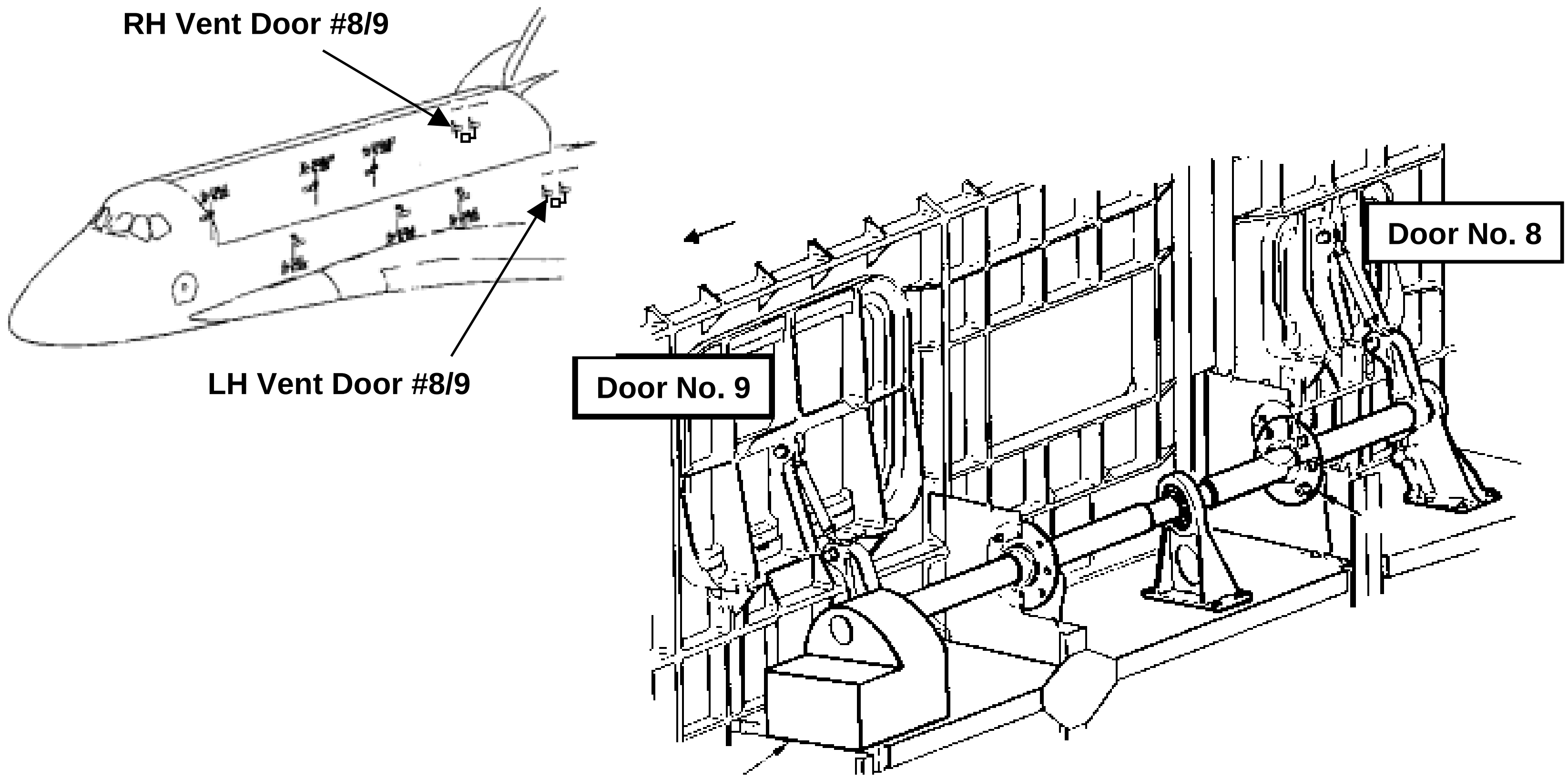


Figure 1: Location of Vent Door 8 & 9 Actuator

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

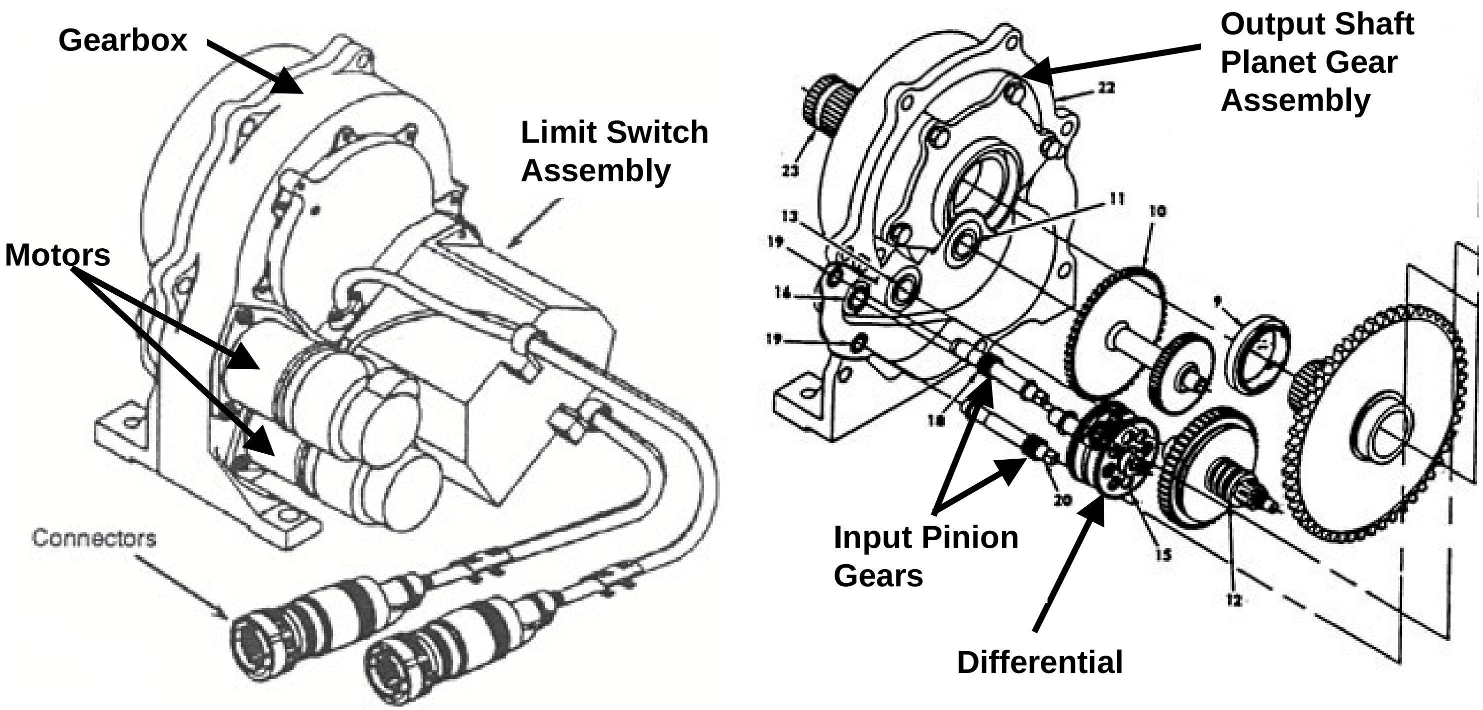


Figure 2: Vent Door 8 & 9 Actuator

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

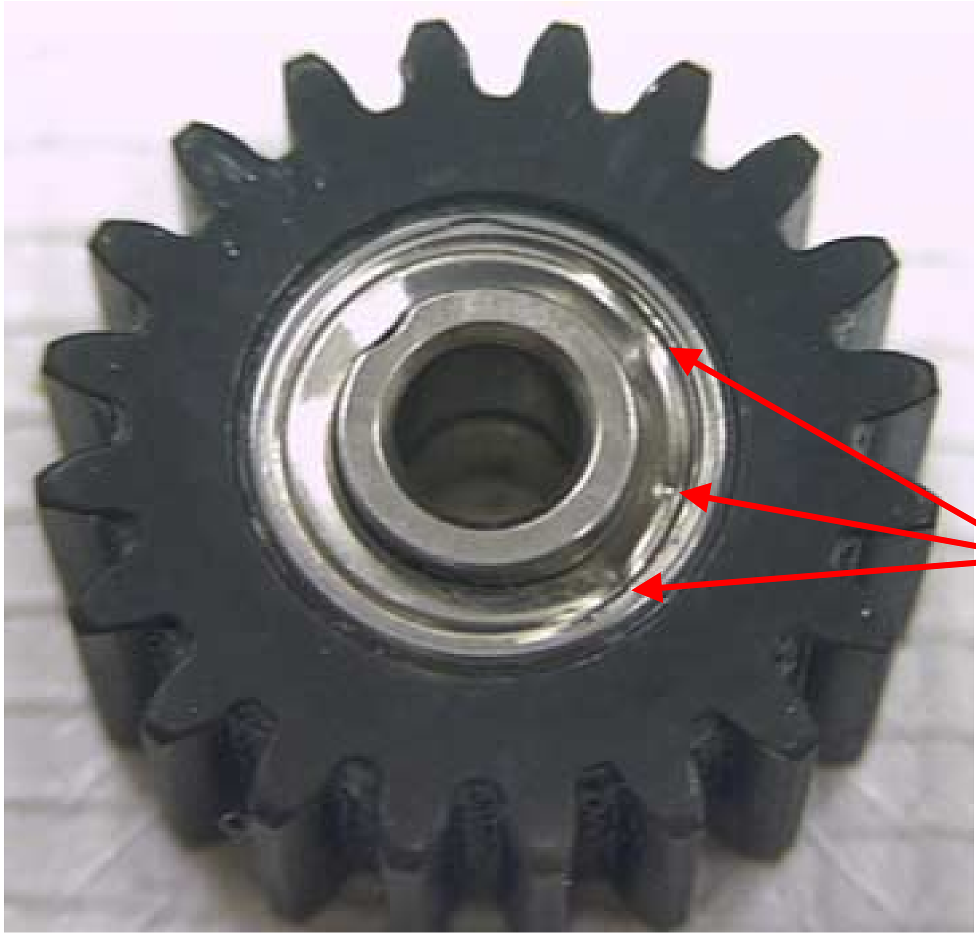


Figure 3: Output Shaft Planet Gear with Damaged Bearing Shield

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

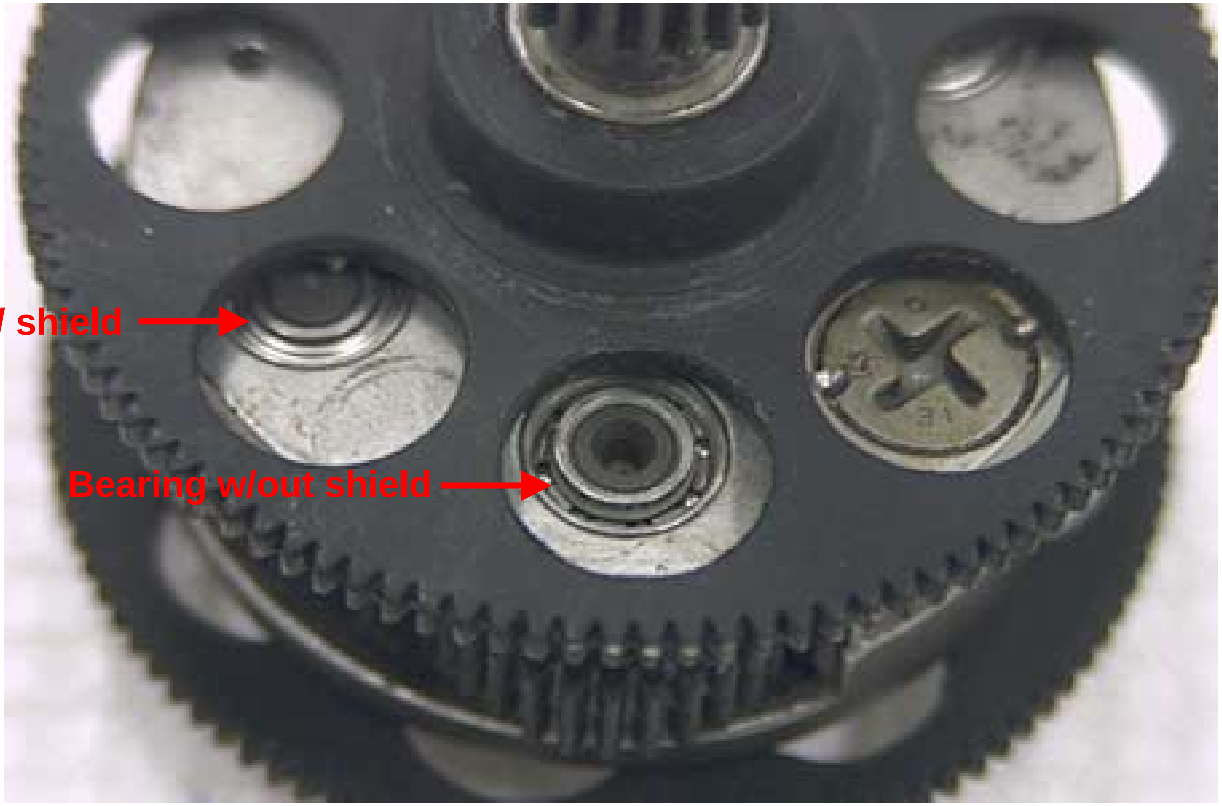


Figure 4: Differential Bearing Missing Shield

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Actions Taken:

- PRT evaluated implications of findings
  - Binding, damaged bearing retainer/cover are undesirable conditions, but not major concerns for actuator operation
    - Most likely due to improper original assembly
    - Actuator has been functioning properly for 18 years, 21 flights
    - Actuator passed recent ATP with no gearbox rework
  - Loose bearing retainer/covers are concern for gearbox jam
    - Also most likely due to improper original assembly
    - Unrestrained FOD could have migrated into gear train instead of sticking to gearbox housing wall

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD	Presenter: Doug White Organization/Date: Orbiter/11-15-01

Actions Taken (Cont):

- PRT concluded improper assembly was the most likely cause of loose shields
  - Two shields could have been installed on one side of bearing
    - Demonstrated at NSLD
  - As a result of extra thickness, retainer wire not seated properly
  - Shields dislodged when differential rotated at operating speed
  - Multiple assembly problems in same unit
- Six other Ellanef actuator gearboxes have been opened at NSLD in the past with no FOD found
  - 4 Vent Door, 2 Star Tracker Door
- All Ellanef actuators on OV-105 have been installed since first flight (16 flights total)
- Review of GIDEP failure history and discussions with bearing manufacturer indicate no prior history of this type of bearing problem

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Risk Assessment:

- **Vent Door** - Worst-case failure is criticality 1R/2 gearbox jam
  - If jam occurs on any door prelaunch, RSLS will halt countdown when vent door does not open in 10 sec
  - Doors are closed for EI and then opened prior to landing - if both (LH and RH) doors jam, associated compartment will not be vented, and delta-pressure loads could damage structure
    - LH & RH doors are redundant to each other
  - Low likelihood of failure
    - FOD required to be in two OV-105 actuators (LH & RH) on same compartment
    - Smart debris required to jam gearbox
      - Bearing shields are small (≈0.010” thick, 0.20 dia.) 302 CRES

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Risk Assessment:

- **Air Data Probe** - Worst-case failure is criticality 1R/2 gearbox jam
  - Probes are deployed prior to landing
  - The two air data probes are redundant to each other
  - If both (LH and RH) probes failed stowed, loss of all air data
- **Star Tracker Door** - Worst-case failure is criticality 1R/2 gearbox jam in open position
  - Doors closed prior to entry
  - If both doors failed open, plasma flow through cavity can cause critical damage to structure
- **Manipulator Retention Latch (MRL)** - Worst-case failure is criticality 1R/3 gearbox jam in unlatched position
  - RMS is latched prior to MPM stow
  - 2 of 3 MRL's latched required for entry
  - If two or more MRL's failed unlatched, RMS can be jettisoned

VENT DOOR 8 & 9 ACTUATOR GEARBOX FOD

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Acceptable for STS-108 Flight:

- FOD condition most likely limited to S/N 16 at NSLD
  - No other history of like condition during disassembly of six other actuators
  - No GIDEP failure or manufacturer failure history of this type of bearing problem
- Worst-case failure is 1R/2 or launch scrub
  - Low likelihood of smart failure required to jam gearbox in redundant actuators
- All Ellanef actuators installed OV-105 have flown 16 flights with no gearbox anomalies
- All OMRSD functional testing on OV-105 successfully completed

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Observation:

- During disassembly / inspection of S/N 403 rudder/speed brake (RSB) power drive unit (PDU) at Hamilton Sundstrand, scuffing was observed on gears adjacent to the motor/brake

Concern:

- Unknown effects of continued use of gears in this condition

Background:

- S/N 403 RSB PDU was originally removed from OV-104 and returned to Hamilton Sundstrand as part of HVM spool stop investigation
- Gearbox disassembly and inspection was initiated because this PDU experienced a four-channel by pass at Palmdale
  - Inspect for possible damage to internal mechanical stops

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

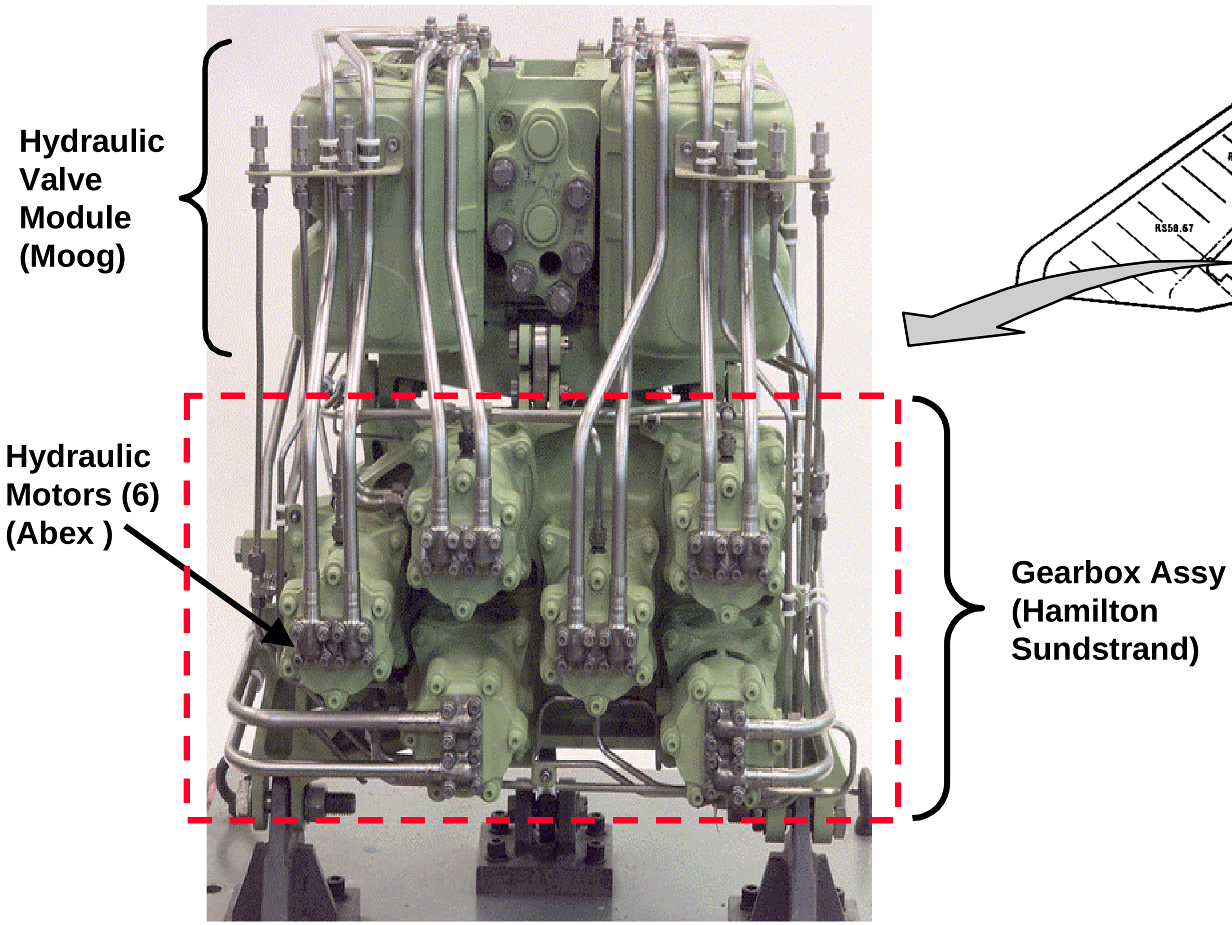
Background (Cont):

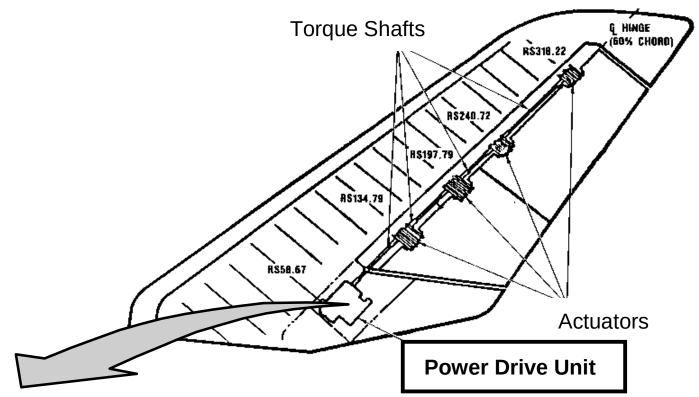
- During gearbox disassembly, scuffing was found on two gears in speedbrake system # 2
  - Scuffing is defined as localized damage caused by the occurrence of solid-phase welding between sliding surfaces
    - Caused by combination of high heat, gear speed, or load
    - May occur in any sliding and rolling contact where the oil film becomes too thin to separate the surfaces
    - Accompanied by the transfer of metal from one surface to another due to welding and tearing
    - In an extreme worst-case scenario, could generate sufficient debris to jam gearbox (Crit 1/1)
  - Scuffing observed on gears 5 and 6, on only one side of the gear teeth, in the tooth-tooth contact area
    - See illustrations on following pages
    - Corresponds to Speedbrake close direction
  - Limited to surface of gear teeth
- Scuffing edges exhibit polishing on gear 5
  - Indicates scuffing was a limited event followed by nominal operation

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:	Doug White
Organization/Date:	Orbiter/11-15-01

Rudder/Speedbrake Power Drive Unit (PDU)

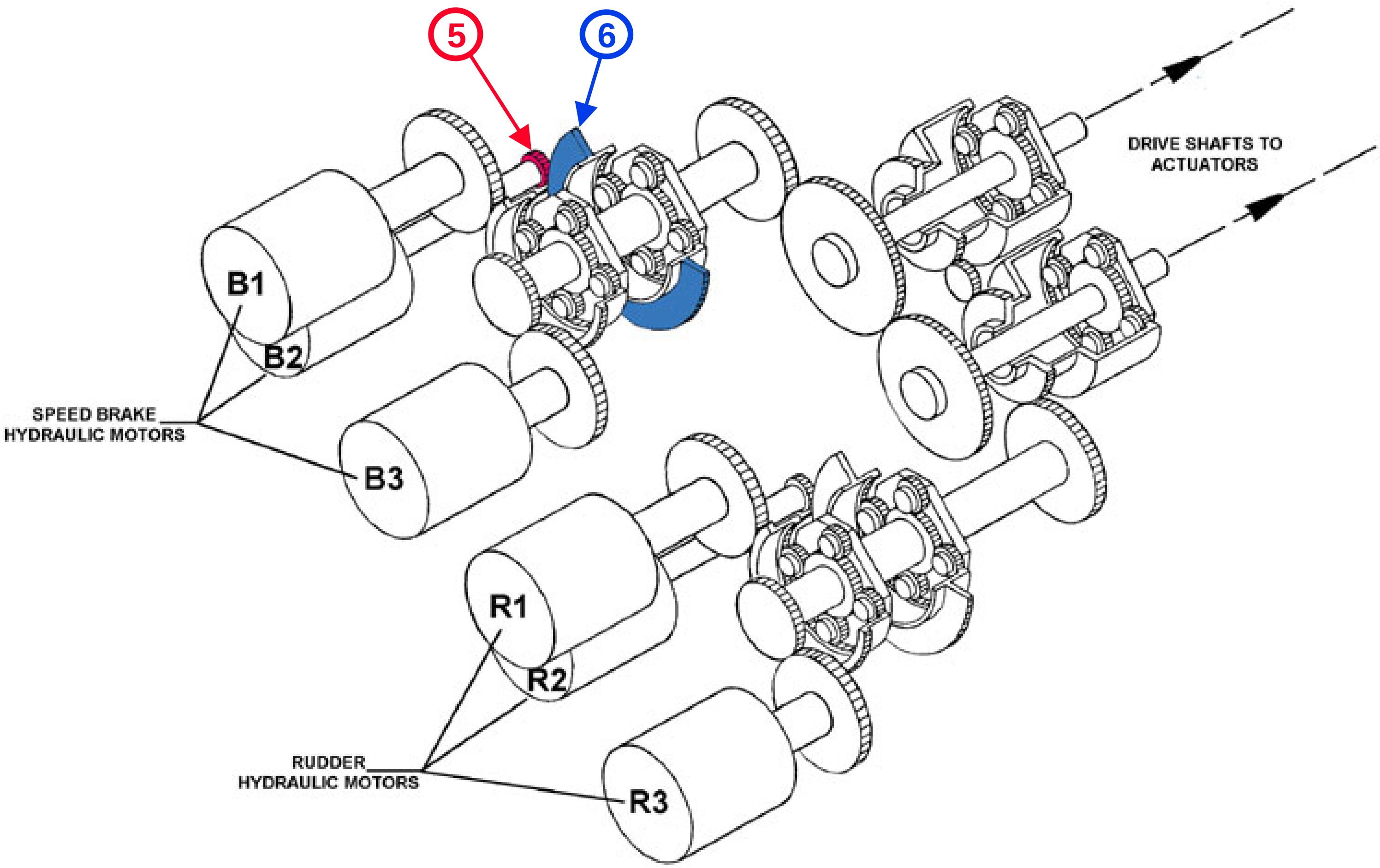




RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

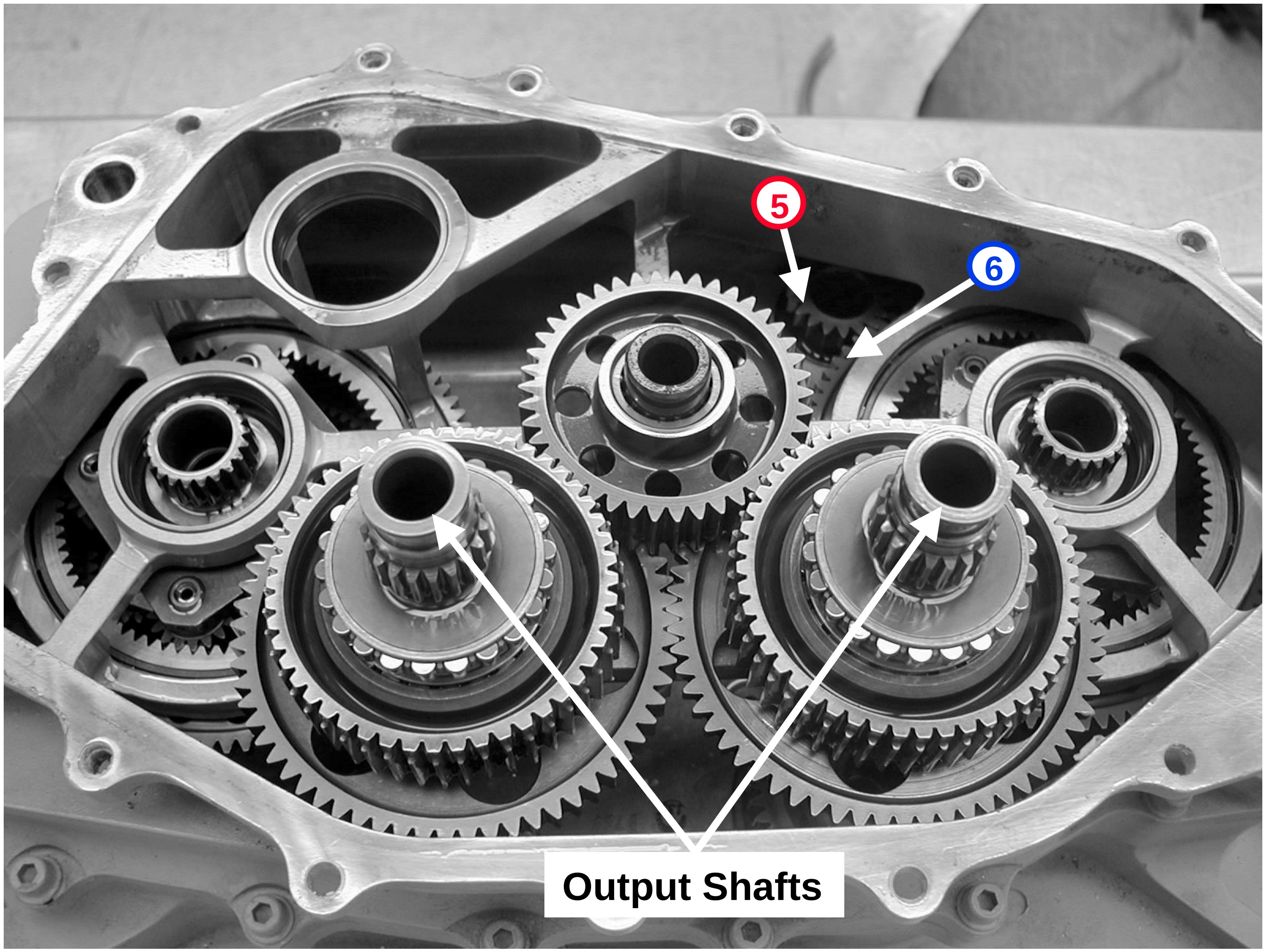


RUDDER/SPEED BRAKE GEAR TRAIN SCHEMATIC

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter: Doug White

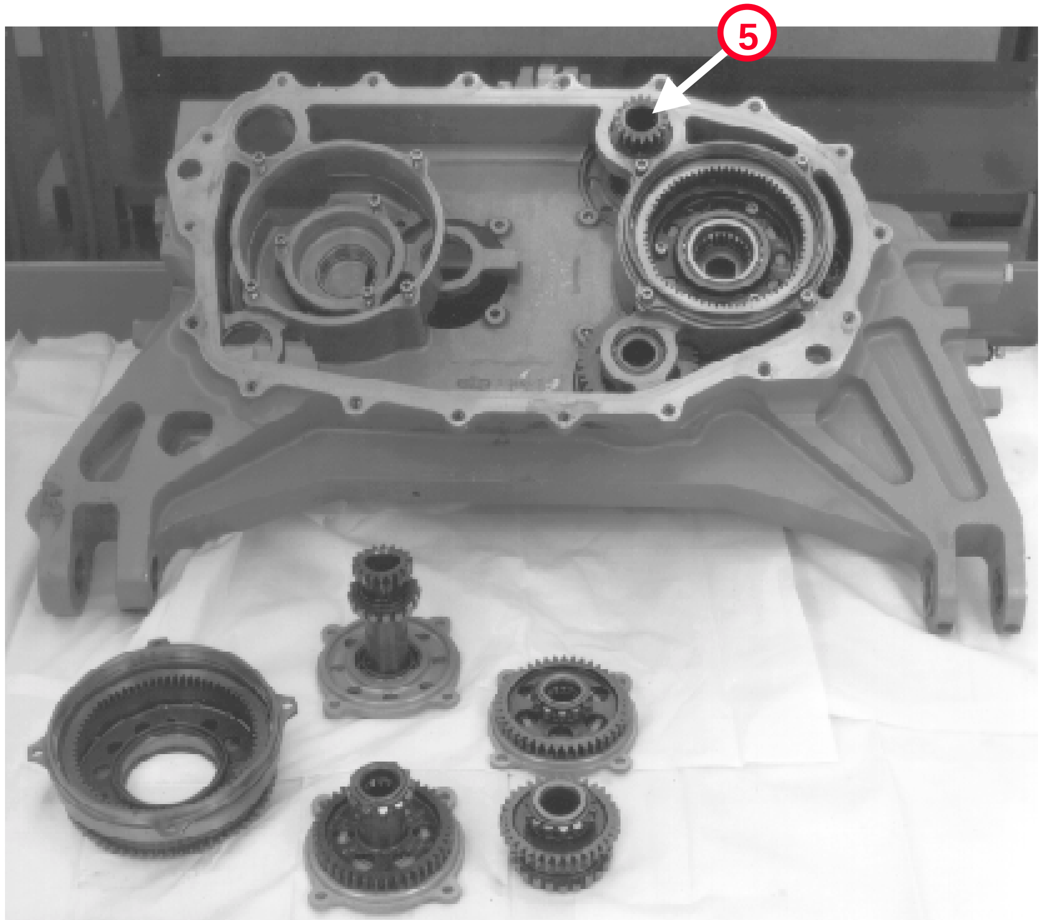
Organization/Date: Orbiter/11-15-01



RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01



RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:
Doug White

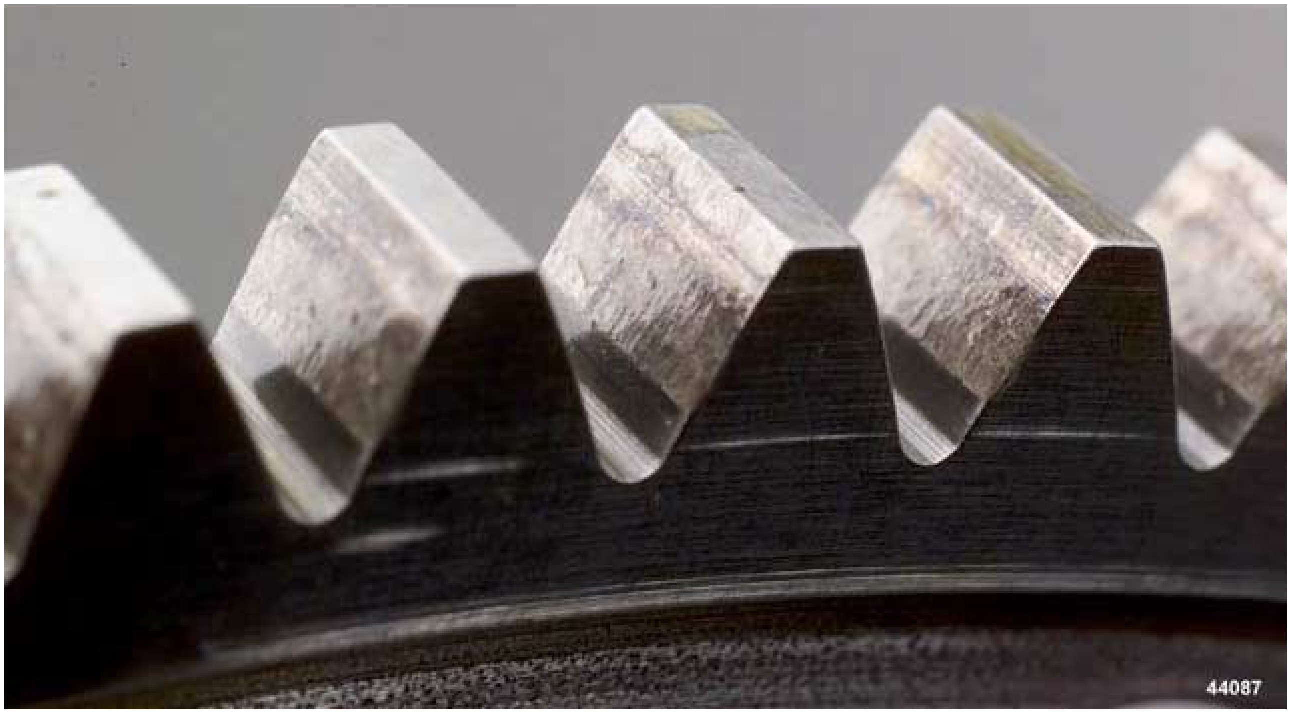
Organization/Date:
Orbiter/11-15-01

Scuffing on input gear, P/N 5001517, S/N D5G014, on one side of gear teeth. Polishing over the scuffing edges indicates that the gear most likely operated in this condition for some time. This gear connects with the Speedbrake System 2 hydraulic motor directly through a series of splined shafts. During normal operation, it drives p/n 5001513 ring gear (next page) either clockwise or counter clockwise.

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01



Scuffing on ring gear, P/N 5001513, S/N D5K012, on one side of gear teeth. During normal operation, it is driven by the input gear (previous page).

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter: Doug White

Organization/Date: Orbiter/11-15-01

Actions Taken:

- Hamilton Sundstrand initiated investigation
  - Visually inspected gearbox oil for debris
    - No unusual debris size or quantity
  - Initial gear inspection, photography
    - M&P evaluation indicated extent of scuffing does not present a near term concern
  - Gear profiling
    - Verified nominal shape, dimensions
  - Material analysis determined there were no off-nominal gear characteristics that could lead to scuffing
    - Magnetic particle inspection
    - Surface hardness, core hardness, case depth
    - Micro-structure
    - Alloy verification
    - Results show gear characteristics to be per print

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

Actions Taken (Cont):

- PRT developed fault tree, identified two most likely causes:
  - Off-nominal gear characteristics cause gears to be more susceptible to scuffing under normal conditions
    - Eliminated - gear characteristics determined to be nominal
  - Hydraulic motor backdrive through gearbox results in motor overspeed - most likely cause
    1) With speedbrake commanded overclosed, hydraulic pressure dropped in only one system reduces output torque of one motor
    2) If pressure high enough to keep brake disengaged, output torque from other two motors overcomes first motor and causes it to drive in opposite direction
    3) Backdriven motor rotates at double the rate of driving motors
    4) Backdriven motor begins to act as hydraulic pump, raises pressure in system, keeps brake disengaged
    5) Situation continues until pressure on other systems drops

    - S/N 403 PDU has had at least three instances of backdrive (of 5 in fleet history), two of which were on system 2

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Actions Taken (Cont):

- Flight data review shows five total backdrive instances in the fleet
  - STS-36 (PDU S/N 403), motor 1 for 6 minutes
  - STS-54 (PDU S/N 407), motor 3 for 45 sec, motor 1 for 1 sec
  - STS-74 (PDU S/N 403), motor 2 for 4 seconds
  - STS-79 (PDU S/N 403), motor 2 for 23 seconds
- System 2 pinion/ring gear interface is more prone to scuffing than systems 1 and 3
  - Different gear geometry required due to higher gear reduction
    - Small pinion versus large ring gear

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

Actions Taken (Cont):

- Scuffing probability analysis program run for known backdrive cases
  - Determines probability of scuffing onset at various combinations of temperature, pinion speed, and horsepower
  - Confirmed that System 2 is more prone to scuffing than Systems 1 and 3
  - Indicated low probability of scuffing in steady-state backdrive
  - Indicated higher probability of scuffing during transient conditions at start of backdrive
    - Worst case stack up of temperature, pinion speed and horsepower variables approach 50% probability of scuffing
    - From beginning of backdrive until pressure equalizes in hydraulic supply line
  - In transient case, there is also some risk to System 2 gears while backdriving System 1 or 3
    - Lower risk than System 2 backdrive
  - For Systems 1 and 3 gears, low probability of scuffing in all cases

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Actions Taken (Cont):

- Flight Controls PRT reviewed operational data
  - Functional tests performed every flow in the OPF and at the pad
    - Individual motor tests include rate confirmation
    - Position tests include full travel confirmation
  - Frequency Response Testing (FRT) performed every 4 flights on pad
  - Scuffed condition has caused no changes in PDU s/n 403 performance data after 22 flights
  - S/N 404 PDU (OV-105) performance has been nominal to date
    - 16 flights on PDU
    - No instances of backdrive
    - FRT performed this flow confirmed performance

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Risk Assessment:

- Extremely low probability of Crit 1/1 failure during STS-108
  - Requires loss of hydraulic pressure in one system (early APU shutdown)
  - Backdrive is a rare event, even with loss of hydraulic pressure
    - 5 instances in entire fleet history
  - Scuffing does not occur with every backdrive incident
    - Worst case stack up of temperature, pinion speed and horsepower variables approach 50% probability of scuffing
  - Scuffing duration must be long enough to generate debris capable of jamming gears
    - No technique available to analyze duration

RUDDER/SPEEDBRAKE PDU GEAR SCUFFING

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

Acceptable for STS-108 Flight:

- OV-105 S/N 404 PDU performance has been nominal
  - No history of backdrive incidents
- Extremely low probability of crit 1/1 gearbox jam
  - Backdrive is a rare, even with loss of hydraulic pressure
  - Scuffing does not occur with every backdrive
  - Scuffing probability highly dependent upon combination of temperature, speed, and horsepower variables
- Analysis results and M&P evaluation of S/N 403 gears indicate no near term concerns with gear condition
  - Scuffing is limited to gear tooth surface - gear tooth material found to be otherwise nominal
  - Scuffed gear condition has had no effect on PDU s/n 403 operation
- OV-105 Rudder/Speedbrake system function has been verified this processing flow

MLG WHEEL TIE-BOLT HOLE CORROSION

Presenter:
Doug White
Organization/Date:
Orbiter/11-15-01

Observation:

- Main landing gear (MLG) wheels at Goodrich show signs of corrosion in critical tie-bolt hole locations

Concern:

- Condition of the wheels on OV-105 is unknown
  - If corrosion exists, it could lead to stress concentration points, causing formation of a crack with eventual failure during landing/roll out

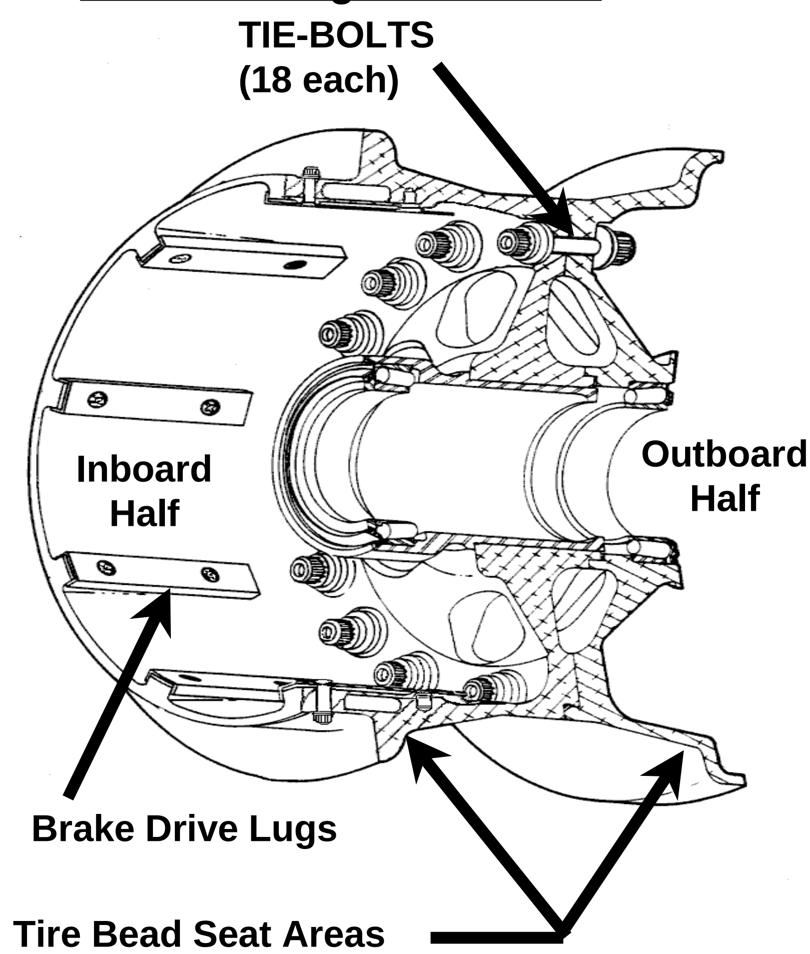
MLG WHEEL TIE-BOLT HOLE CORROSION

Presenter: Doug White
Organization/Date: Orbiter/11-15-01

Discussion:

- The Orbiter's MLG wheel is a typical aircraft split wheel design
  - Aluminum wheel halves
    - Chemical film coating and primer/top coat provide corrosion protection
    - Holes And Wheel Halves Mating Surfaces have chem film and primer only
  - High strength Multi-Phase tie-bolts assemble the inner and outer wheel halves together
  - MLG wheels are designated as fracture critical hardware
- Wheels are disassembled and assembled every flow due to one flight use of MLG tire

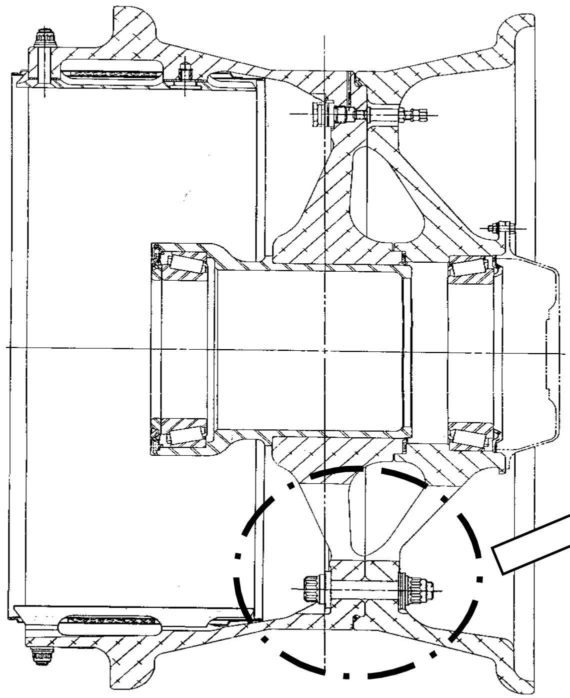
Main Landing Gear Wheel



MLG WHEEL TIE-BOLT HOLE CORROSION

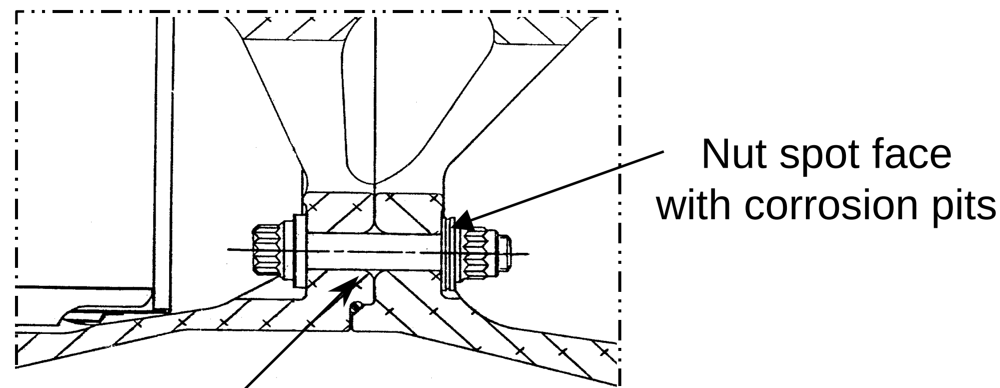
Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01



MLG Wheel

Typical Tie Bolt attachment



MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

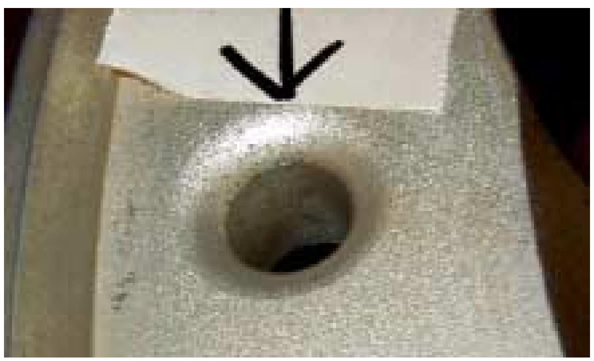
Discussion: (cont)

- During the scheduled 10 flight refurbishment of MLG wheels at Goodrich, visual inspection revealed signs of corrosion pits in tie-bolt hole areas
  - Corrosion on the edge radius of holes, washer bearing surfaces, and inside some holes (areas with chem film and primer only, no white top coat)
  - No cracks were discovered during NDI inspection (dye-penetrant)
- To increase the sample size, an additional set of 7 wheels were sent to Goodrich for inspection
  - Visual appearance of the corrosion was similar to the first group of wheels
- To further increase the sample size, OV-103 wheels were sent to Goodrich, bringing the total to 17
  - Visual appearance of the corrosion was similar to the first group of wheels

MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Tie Bolt Hole Corrosion

View Showing Outboard Face of Wheel Half



View Showing Inboard Face (Mating Surface) of Wheel Half

MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Actions Taken/In Work:

- An investigation is being conducted to determine the root cause(s) of wheel corrosion
  - Fault tree generated to document all known/hypothesized corrosion mechanisms (see back-up)
    - Installation related damage to corrosion protection (i.e., alignment pin, bolt)
    - Environmental exposure, moisture from rain, or the effect of condensation following cold soak and/or re-entry
    - Galvanic interaction between dissimilar metals (i.e., MP35N bolt and aluminum wheel)
    - Cleaning materials and methods (chloride containing cleaner)
    - Other materials used in the wheel (i.e., carbon brake dust, moly disulfide lubricant, etc)

MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Actions Taken/In Work: (cont)

- To date, the investigation has not provided any reason to believe that the severity of corrosion on OV-105 wheels is any worse than that seen on the wheels at Goodrich
- Reviewed wheel processing procedures, timelines and exposure environments and determined that, in general, all wheels are processed utilizing the same procedures and to a similar turnaround timeline
  - One difference discovered to date is that some of the wheels at Goodrich have been exposed to carbon dust for long durations of time (up to 26 months), and OV-105 wheels have not
    - No correlation between observed pit depths and storage time in brake dust

# MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Actions Taken/In Work: (cont)

- Initiated quantitative inspection activity at Goodrich to determine severity (quantity and depth) of corrosion for evaluation against material flaw size allowables
- Of the 30 wheels in the fleet, 17 have been inspected at Goodrich and 35 corrosion pits on 4 wheels have been machined to measure total depth
  - 2 of these wheels (S/N's 029 & 30M) were given priority because the corrosion visually appeared to be worst, the other 2 (S/N's 75M & 42) were selected because the severity of the corrosion visually appeared medium - light
    - Sampling has corroborated that there is correlation between the visual appearance of the corrosion damage site depth and the actual depth as determined by machining
- Conservative sampling has provided confidence that there is a high likelihood that the results of measurements taken to date envelope the worst corrosion that may exist on any wheel in the fleet, including those on OV-105
  - Single worst corrosion depth measured to date is 0.0385 on S/N 30M
  - Next worst couple of depths 0.023 – 0.027
  - Mean = 0.0112

MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Corrosion Depth Measurements

Wheel S/N 029 Outboard Half Corrosion Summary

Hole Number	Pits	Size (in)	Location
4	2	0.0075	bore
	1	0.015	bore
	1	0.016	bore
	1	0.025	bore
	3	0.008	radius
14	1	0.01	bore
	1	0.017	bore
15	1	0.01	bore
	1	0.013	bore
	1	0.011	radius
16	1	0.01	bore
	1	0.023	bore
17	2	0.01	bore
	1	0.012	bore
9	1	0.02	radius, destructive eval

Wheel S/N 30M Outboard Half Corrosion Summary

Hole Number	Pits	Size (in)	Location
8	1	0.0385	radius
18	1	0.027	radius

Wheel S/N 75M Outboard Half Corrosion Summary

Hole Number	# of Pits	Size (in)	Location
4	3	0.0145	bore
8	3	0.0025	bore
12	1	0.0025	bore
	2	0.008	bore
	1	0.014	bore

Wheel S/N 42 Outboard Half Corrosion Summary

Hole Number	# of Pits	Size (in)	Location
2	1	0.003	bore
7	1	0.0025	radius
10	2	0.0025	bore
	1	0.0015	radius

MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White **Organization/Date:** Orbiter/11-15-01

Actions Taken/In Work: (cont)

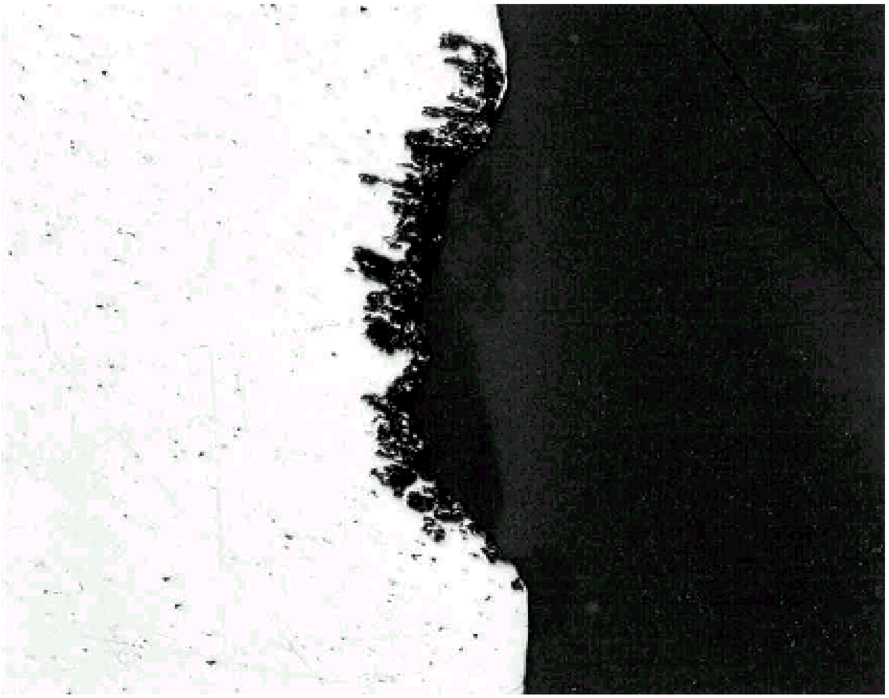
- 1 wheel (S/N 029) has been destructively tested
  - Metallography performed on four corrosion cross-sections to characterize the pit morphology has provided confidence in corrosion depth findings determined via machining
  - Additional validation of the machining process will be performed to verify that the machining process is not leaving any remaining corrosion
    - A site which has already been machined and appears visually/10X to be free of corrosion damage will undergo metallographic analysis to ensure all corrosion has actually been removed

MLG WHEEL TIE-BOLT HOLE CORROSION

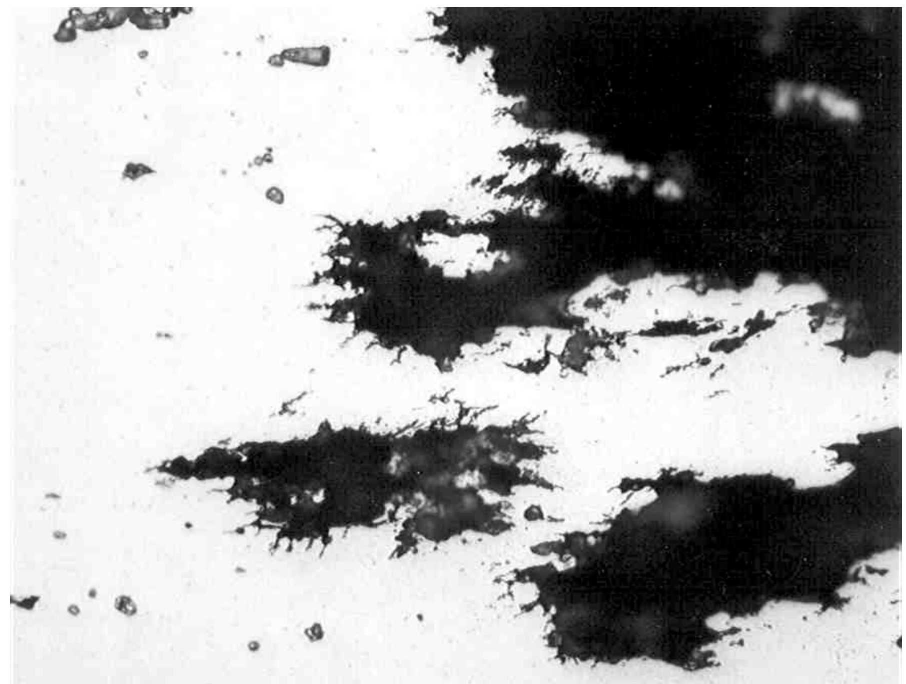
Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Corrosion Cross Section



50X magnification



400X magnification

MLG WHEEL TIE-BOLT HOLE CORROSION

Presenter:
Doug White

Organization/Date:
Orbiter/11-15-01

Actions Taken/In Work: (cont)

- Fracture analysis performed at Goodrich in 1989 predicted that if an 0.030 deep x 0.060 wide initial flaw existed in the critical surface area, it would go unstable during the 6^{th} mission
  - Results in a crack between tie-bolt holes
  - Not necessarily loss of the wheel, but stresses change (considered a crit 1/1 event)
- 1989 fracture analysis used a constant load distribution on a flat plate
- Performing a new, more realistic, analysis was determined to be beyond the limits of available fracture analysis tools
  - Attempts to force a more realistic stress field assumption (whereby the stress level a corrosion crack has to endure diminishes as it moves away from the hole) have been unsuccessful
  - Attempts to make a conservative approximation of lower stress ratios revealed undesirable sensitivity in fracture analysis calculations
  - Fracture analysis methodology is not reliable when stress levels are between F_{ty} and F_{tu}

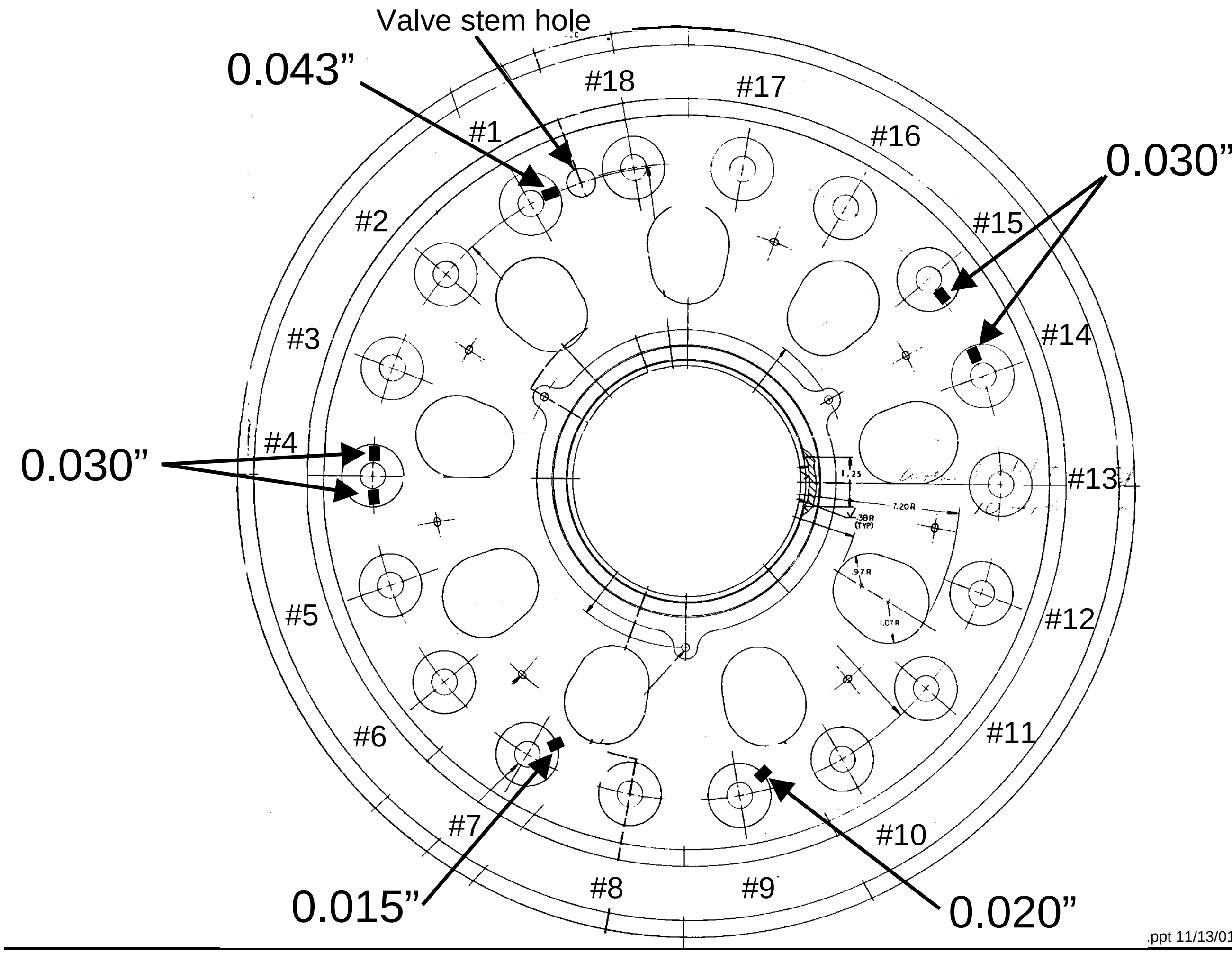
MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Actions Taken/In Work: (cont)

- In lieu of analysis, a test is being run to demonstrate the wheel's corrosion damage tolerance
  - An outboard wheel half with naturally occurring corrosion sites was selected and 7 additional flaws were artificially induced with a plunge EDM tool
    - Worst case flaw size of 0.043" deep x 0.090" long x ~0.005" wide in the worst orientation and located in the peak stress location
      - Peak stress location determined from finite element model (ref. back-up charts)
    - Two 0.030" deep x 0.060" long x 0.005" wide flaws emanating in opposite directions from a single hole and two 0.030" deep x 0.060" long x 0.005" wide flaws emanating towards each other from adjacent holes
      - Intended to characterize how multi-site damage affects wheel's residual strength
    - A 0.020" deep x 0.040" long x 0.005" wide flaw in the worst orientation and located in the peak stress location
    - A 0.015" deep flaw sized to allow direct comparison to similarly-sized naturally occurring corrosion sites

MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Test Wheel Flaw Locations



MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Actions Taken/In Work: (cont)

- WPAFB assembled two wheel/tire test specimens and will run 4 landing profiles (3 nominal and 1 abort case)
  - Case #1 – 110,000 lbs, above average (100,000 lbs) but below maximum flight experience (~123,000 lb radial load on wheel)
  - Case #2 – 125,000 lbs with light cross wind (slightly above flight experience)
  - Case #3 – 128,000 lbs with light cross wind (slightly above fight experience)
  - Case #4 – 145,000 lbs with strong cross wind (abort condition, well above flight experience)
- To mitigate the safety risk to personnel and the risk of damaging WPAFB test equipment, a 'slow roll' test will be run and at the conclusion of each profile, the wheel will be disassembled and dye penetrant/eddy current inspected for flaw growth
  - Analysis will also be used to achieve correlation before continuing with the next, more severe, load case
- Results of testing to be reported at STS-108 L-2 Review

MLG WHEEL TIE-BOLT HOLE CORROSION	Presenter: Doug White
	Organization/Date: Orbiter/11-15-01

Risk Assessment and Acceptability For Flight:

- Investigation into the root cause of the wheel corrosion has not provided any reason to believe that the severity of corrosion on OV-105 wheels is any worse than that seen on the wheels at Goodrich
- Conservative sampling has provided confidence that measurements taken to date envelope the worst corrosion that may exist on OV-105 wheels
- Testing is in work to demonstrate wheel's corrosion damage tolerance
  - Attempting to assure that even if a crack equivalent to the worst corrosion site in the sample data set exists on OV-105 wheels, with the worst orientation and in the peak stress location, STS-108 is safe to fly
- Results of testing to be reported at STS-108 L-2 Review

	Presenter:
	Organization/Date: Orbiter/11-15-01

FLIGHT READINESS STATEMENT

SPACE SHUTTLE VEHICLE ENGINEERING OFFICE

STS-108 (OV-105) ☐ **ORR** ☒ **FRR** ☐ **Prelaunch MMT**

Pending completion of scheduled open work, the Orbiter vehicle, support hardware, flight crew equipment, and software are certified and ready to support. For United Space Alliance accountable functions, insight, audit, and surveillance activities have been reviewed, and there are no constraints to flight.

ORBITER / FLIGHT SOFTWARE / FLIGHT CREW EQUIPMENT

P. E. Shack, Manager, Shuttle Engineering Office

F. A. Ouellette, Manager, Flight Crew Equipment Management Office

D. E. Stamper, TMR, Software

P. A. Petete, Acting TMR, Orbiter and Flight Crew Equipment

REMOTE MANIPULATOR SYSTEM

S. Higson, Program Director, SRMS
McDonald Dettwiler and Advanced Robotics Limited

R. Allison, RMS Project Manager 31 Oct 01

SPACE VISION SYSTEM

L. Beach, Program Manager, SVS
NEPTEC

D.S. Moyer, SVS Integration Office 10/31/01

FERRY FLIGHT PLANNING

D. L. McCormack, Ferry Flight Manager 10/31/01

Ralph R. Roe, Manager
Space Shuttle Vehicle Engineering

FRRS-2

USA SSVEO Functions

STS-108 (OV-105) FLIGHT READINESS STATEMENT

☐ ORR ☒ FRR ☐ Prelaunch MMT

PENDING COMPLETION OF SCHEDULED OPEN WORK, THE ORBITER VEHICLE, SUPPORT HARDWARE, FLIGHT CREW EQUIPMENT, AND SOFTWARE ARE CERTIFIED AND READY TO SUPPORT.

ORBITER / FLIGHT SOFTWARE

Greg Ray
G. A. Ray, Program Director, Orbiter
Human Space Flight and Exploration
The Boeing Company

J. Wilder, Associate Program Manager
Orbiter Element
United Space Alliance

T. F. Peterson, Associate Program Manager
Flight Software Element
United Space Alliance

FLIGHT CREW EQUIPMENT

E. L. Young, FCE/EVA Associate Program Manager
United Space Alliance